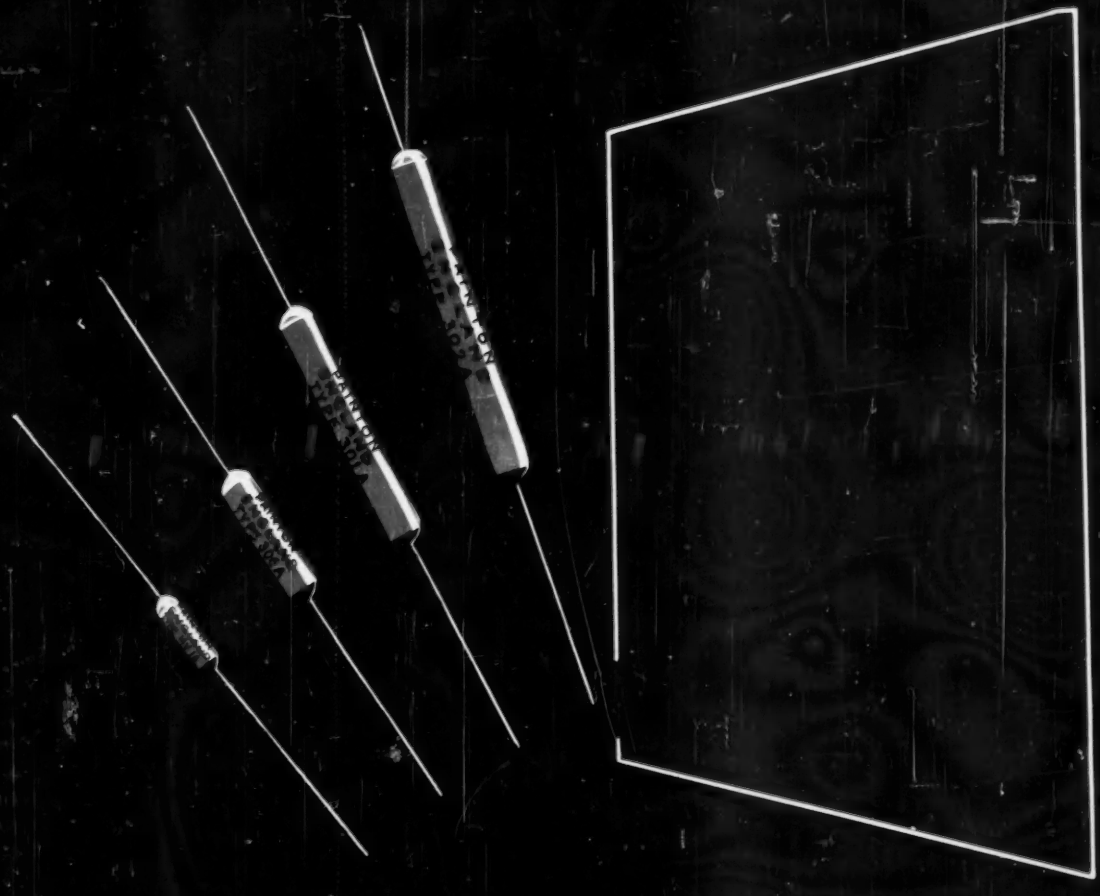
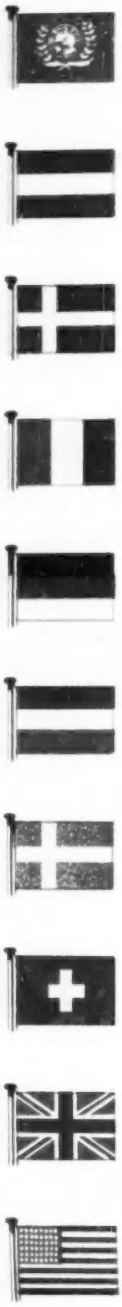
# Electronic Engineering



# INTERNATIONAL IN INSTRUMENTATION



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# CLASSIFIED ADVERTISEMENTS

**The charge for these advertisements is 6d. per word. Minimum charge 12/-. Box number 2/- extra, except in the case of advertisements for "Situations Wanted," when it is free. Specially spaced advertisements per inch single column 42/6. A remittance must accompany the advertisement. Replies to Box Numbers should be addressed to: "Electronic Engineering," 28, Essex Street, Strand, London, W.C.2. Advertisements must be received before the 14th of the month for insertion in the following issue**

## OFFICIAL APPOINTMENTS

**ATOMIC ENERGY RESEARCH ESTABLISHMENT**, Harwell, requires an Experimental Officer to assist in development of instruments and equipment including contracts liaison and to supervise the personnel monitoring film service of the Health Physics Division. G.C.E.(A); H.N.C., or equivalent essential. Radiation dosimetry or photographic experience an advantage. Salary: £990-£1,215. Housing: superannuation; excellent conditions. Send postcard for application form and details to Recruitment Officer (952Z/42), A.E.R.E., Didcot, Berks. W 2673

**CITY OF BIRMINGHAM EDUCATION COMMITTEE.** Garretts Green Technical College, Garretts Green Lane, Birmingham, 33. Principal: B. C. Whitehouse, B.Sc., A.R.I.C. Applications are invited for the following full-time teaching posts. Assistant, Grade B, to teach subjects of O.N.C. Electrical Engineering and C. and G. Electrical Installation Courses. H.N.C. or equivalent qualification required. Assistant, Grade B, to teach subjects of the C. and G. Telecommunications Engineering and Radio Servicing Courses. H.N.C. or equivalent qualification required. Salary scale: Assistant, Grade B £650 × £25—£1,025. In all cases when assessing the initial salary, increments may be allowed for appropriate experience in Industry or Commerce, in addition to increments for training and Degree or Degree equivalent. Application forms and further particulars available from the Principal (foolscap s.a.e.), to whom completed forms should be returned as soon as possible. E. L. Russell, Chief Education Officer. W 2678

**CITY OF BIRMINGHAM EDUCATION COMMITTEE.** Matthew Boulton Technical College. Principal: J. C. Martin, M.A. (Cantab.), A.M.I.E.E., A.M.Brit.I.E.E. Required from 1st September, 1958: Lecturer to teach City and Guilds Telecommunication Courses including Mathematics to Final Level. Burnham (Further Education) Salary Scales: Lecturers £1,200 × £30—£1,350. Application forms and further particulars from Room 52 (foolscap S.A.E.) Education Office, Margaret Street, Birmingham, 3, and completed forms should be returned not later than 3rd January, 1958. E. L. Russell, Chief Education Officer. W 2686

**ELECTRICAL/ELECTRONIC ENGINEER** required at the Atomic Energy Research Establishment, Harwell, to operate and maintain a nuclear physics machine consisting of 28 MeV electron accelerator used to bombard uranium and so to produce intense neutron pulses for nuclear experiments. Applicants should have a professional qualification. An Electrical Engineering Degree and experience of high vacuum or high frequency techniques, or of electro-mechanical plant, is desirable. Salary: £815 (at 25) to £1,270. Housing, superannuation and excellent conditions. Send postcard to Recruitment Officer (902Y/42), A.E.R.E., Didcot, Berks. W 2685

**PRINCIPAL AND SENIOR SCIENTIFIC OFFICERS** required by the Atomic Weapons Research Establishment, Aldermaston, Berkshire, to lead small teams carrying out original research in electronics. These deal with a wide variety of interesting problems which arise in nuclear physics and which cannot be solved by presently available techniques and equipment. Applicants should have a first or second class Honours Degree, preferably in physics or electrical engineering, and should have conducted independent research in suitable aspects of electronics. These include ultra-fast time measurements, general electronic circuit design, transistor circuit design, information handling techniques and the design of special electronic tubes. Salary: P.S.O. £1,460-£2,080 p.a. S.S.O. £1,215-£1,425 p.a. Contributory Superannuation Scheme. A house or assistance towards legal expenses on house purchase will be available for married officers living beyond daily travelling distance. Postcards for application forms to the Senior Recruitment Officer at above address. Please quote ref. 1647/42. W 2672

**COMMONWEALTH OF AUSTRALIA.** Commonwealth Scientific and Industrial Research Organization, Division of Plant Industry. Appointment No: 130/324 of Electronics Engineer. The Division of Plant Industry is concerned with research into many aspects of agriculture and biology basic to the continued development of Australian primary industry. Its research programmes in Biochemistry, Biophysics, Physiology, Ecology, Microbiology and other fields, both in the laboratory and the field, offer considerable scope for the application of electronic principles and for collaborative research in the electronics field. Applications are invited from graduates interested in this field, to establish an electronics laboratory within the Division at Canberra. The appointee will be required to initiate research into the application of electronics to problems of agricultural research. Applicants should possess a University Honours Degree in Science or Engineering and have had research experience in the fields of instrumentation and applied electronics. Dependent on qualifications and experience, commencing salary will be determined within the ranges of Senior Research Officer £A2,048-£A2,323 or Research Officer £A1,313-£A1,938. The appointment may initially be for a period of three years, although an indefinite appointment would be considered. Appointment will be conditional on a satisfactory medical examination. If appointment is made on an indefinite basis the position will carry Superannuation Fund or Provident Account privileges. In the case of an appointee domiciled overseas, first class sea fares to Australia will be paid for the appointee, his wife and family. If the appointee does not take up an indefinite appointment with the Organization at the expiry of his fixed period, return fares will also be paid. Applications quoting Appointment No. 130/324 and stating full name, place, date and year of birth, nationality, marital state, present employment, particulars of qualifications and experience and war service, if any, accompanied by the names of three professional persons willing to act as referees, and copies of not more than four testimonials should reach the undersigned from whom further particulars may be obtained, not later than the 25th January, 1958. A. Shavitsky, Chief Scientific Liaison Officer, Australian Scientific Liaison Office, Africa House, Kingsway, London, W.C.2. W 2695

**HOME OFFICE:** Wireless Technician. The Civil Service Commissioners invite applications from men for about 50 permanent posts in Pinner, Middlesex, and at Regional Wireless Depots in various parts of England and Wales. Duties include installation and maintenance of radio equipment used by police and fire services. Age at least 22 on 1st December, 1957. Candidates must have sound theoretical and practical knowledge of wireless engineering and communications equipment including V.H.F. apparatus. Possession of C. and G. Certificates, or comparable qualifications, an advantage. Ability to drive a car desirable. Starting pay at Pinner £540 at age 24 (£30 less for each year under 24) up to £630 at age 28. Scale maximum £685. Slightly less at Regional Depots. Promotion prospects. Five-day week. Further particulars and application form from Secretary, Civil Service Commission, Trinidad House, Old Burlington Street, London, W.1, quoting No. S4792/58. Completed application forms to be returned by 6th February, 1958. W 2677

**INSTRUMENT ENGINEERS** required in the Electronics and Instruments Section of the Central Electricity Authority, Research Laboratories, Leatherhead. The Section provides an instrument service for all departments of the Laboratories and duties include the maintenance, calibration and repair of the wide variety of physical, chemical and electrical instruments. Candidates should have the Higher National Certificate and experience in electronic or nucleonic equipment will be an advantage. Salaries within scales £820-£995 p.a., or £550-£725 p.a. Write for application form to D. Moffat, Director of Establishments, Winsley Street, London, W.1, to be completed and returned by 28 January. Quote Ref. E.E./513. W 2696

**RUNWELL (MENTAL) HOSPITAL,** near Wickford, Essex. Physicist required. Graduate of a British University with experience in Electronic Engineering. Duties mainly connected with Department of Electroencephalography; also development of equipment in other departments. National Health Service salary and conditions; pensionable post. Salary: Probationary (for new entrants). Holders of 1st or 2nd Class Honours Degree £525-£625. Other entrants £475-£575. (Starting salary according to post-graduate experience.) After probationary period £650-£845. Applications to Secretary with names of two referees. W 2675

**REACTOR RESEARCH PROGRAMME.** Engineers for (1) operation and maintenance of research reactors; (2) site services, operation and maintenance; (3) electrical and mechanical design of prototype and experimental equipment; (4) manufacture of experimental equipment. The Engineering Division of the Research Group of the United Kingdom Atomic Energy Authority is forming a nucleus staff to man and commission a Research and Development Establishment in Dorset. A wide range of posts will be available in this project but applications are at this time being sought from those interested in joining for initial training at A.E.R.E. Harwell. Candidates should have served a recognized engineering apprenticeship or have had equivalent training and be Corporate Members of a senior Engineering Institution. The possession of an Engineering Degree would be an advantage. Posts are available at the following levels: £815 (age 25)-£1,270 (Eng. III), £1,300-£1,740 (Eng. II), £1,790-£2,080 (Eng. I). Please send a postcard to the Recruitment Officer (993Y/42), A.E.R.E. Harwell, Didcot, Berks. for application form and further details. W 2659

**THE NATIONAL RESEARCH COUNCIL OF CANADA,** Ottawa, Ontario, requires Scientific Staff. Applications are invited for vacancies in the Instruments and Control Systems Laboratory of the Division of Mechanical Engineering. Duties will include development of special instrumentation equipment and systems for laboratory, field and airborne use. Design and development of automatic control systems. Applicants must be graduates or post graduates in Engineering Physics, Electrical Engineering or Mathematics and Physics from a university of recognized standing. Experience in the fields of instrumentation, industrial electronics, computer design, precision gyroscopes or magnetic recording techniques would be an advantage. Starting salary up to a maximum of $8,700 per annum will depend on the qualifications of the successful applicant. Employee benefits include a five-day week, generous provision for vacation and sick leave, medical-hospital insurance plans and an attractive pension scheme. Applications should be directed to the Employment Officer, National Research Council, Sussex Drive, Ottawa 2, Canada. Please quote file ME-497. W 1937

**UNIVERSITY OF NOTTINGHAM,** Departments of Civil and Mechanical Engineering. Honours Graduates in Engineering or Physics are invited to apply for appointments as Senior Research Assistants in the fields of Fatigue of Metals and Photo-elasticity. Salary within the scale £900 to £1,300, with membership of F.S.S.U. and family allowances. Further particulars from the Registrar, to whom applications should be submitted before 15th January 1958. W 2664

**UNIVERSITY COLLEGE OF SWANSEA.** Applications are invited from Electrical Engineers and Physicists or Mathematicians with suitable experience for a Lectureship in Electrical Engineering. Salary on the scale £900-£1,650 per annum. Commencing salary can be at any point on the scale according to qualifications and experience. Membership of F.S.S.U. and children's allowance scheme. Further particulars may be obtained from the Registrar, University College, Singleton Park, Swansea, to whom applications (six copies) must be sent by January 18, 1958. W 1940

## SITUATIONS VACANT

**AMERICAN INDUSTRY** is seeking well-qualified Engineers, Scientists, and Mathematicians for research, development and production. Attractive salaries, liberal benefits, pleasant working and living conditions, challenging projects, substantial opportunity for advancement, expenses of transporting self and family to America paid. For further information please send resume of education and experience to J. F. Howard, P.O. Box 22, West Roxbury, Boston 32, Massachusetts, U.S.A. All replies kept confidential. W 1939

**AN ELECTRONIC ENGINEER** required by well-known instrument Company in London. B.Sc. in Electrical Engineering essential. Age 22-28; to work on transistor circuit development, for very interesting industrial applications. Salary £750-£850. Write Box W 1936.

SITUATIONS VACANT (Cont'd.)

**AN EXCEPTIONAL OPENING** occurs for an experienced man to commence development and manufacture of silicon transistors. This is an important post and carries a substantial salary. Please write in strictest confidence to Managing Director, Microcell Ltd., 56 Kingsway, London, W.C.2. W 2699

**ASSISTANT** to Chief Electrical Engineer required for interesting work on magnetic circuits. B.Sc. Degree or A.M.I.E.E. qualification preferred, previous experience desirable, but not essential. Salary according to qualifications, contributory pension scheme in operation. This is a very attractive opening in a young and progressive unit for a keen worker. Full details in writing to Telcon-Magnetic Cores Limited, The Industrial Estate, Chapelhall, Lanarkshire. W 1919

**ANALOGUE COMPUTING SERVICE.** An Applied Mathematician or Engineer with an interest in Mathematics is required for the application of Analogue Computing techniques to a variety of problems undertaken by the Analogue Computing Service. The required qualifications are at Degree level. Experience is not necessary but electronic development work would be valuable background. Please write to Personnel Manager (Ref. 572), Elliott Brothers (London) Limited, Borehamwood, Herts. W 2692

**A VACANCY EXISTS** in the radio and television laboratories of a leading manufacturer, situated in Eastern London, for a project leader to engage in the development of domestic and car radio. Must be familiar with current circuit techniques, including transistors, and production design for conventional and printed wiring. Minimum qualifications H.N.C. with at least five years' experience in a similar capacity. A contributory pension scheme is in operation and good canteen facilities are available. Please reply, giving full details of experience and qualifications to Box W 2653.

**AUTOMATION.** A Senior Electrical/Engineer is required by a large engineering company, situated in the London area, for design and development work in one or more of the following fields in connexion with current and future mechanisation projects. 1. Electrical control circuits for special purpose machines involving the application of relay and switching techniques to the control and sequencing of a wide variety of machines, handling electrical, electronic and light mechanical products. 2. Electronic test gear for the automatic checking of components, valves and electronic amplifiers on a production scale. 3. Electronic test gear for the production testing of semi-conductor characteristics during manufacture. A Senior Draughtsman is also required for work on the above projects. The positions, which are permanent, offer a generous salary according to qualifications and experience. Good laboratory and staff conditions. Please reply, in confidence, giving full details to Box W 2657.

**BRITISH PETROLEUM COMPANY LIMITED** has a vacancy for an Electronic Engineer for work in the Instrument Group at its Research Station at Sunbury-on-Thames. Applications are invited from men with a University Degree in Physics or Electrical Engineering or equivalent. Some experience in the design and development of electronic instruments preferable. Work will include development of instruments for the control and testing of internal combustion engines, for process control, and for chemical and physical measurements. Age under 35. Salary according to age, qualifications and experience. Non-contributory Pension Fund. Assisted House Purchase Scheme. Removal expenses and settling-in allowance payable in certain cases. Luncheon Club. Write, giving full details quoting H.3303A, to Box 5637, c/o 191 Gresham House, E.C.2. W 2688

**COMPANY** with world-wide interests requires an engineer to test and inspect television distribution systems throughout England and Wales. A salary of up to £1,000 p.a. and all expenses while travelling will be paid. Reply in confidence to Box W 1946.

**COSSOR INSTRUMENTS LTD.,** Senior Engineer, required for circuit development on oscillographs and other instruments. Preference given to a man holding Degree or equivalent academic qualifications, plus five years' design experience; although proven design ability and wider experience would be considered in lieu. For a progressive post with a young and expanding Company within an established group write to The Technical Director, Cossor Instruments Ltd., Highbury Grove, London, N.5. W 2689

**DATA PROCESSING SYSTEMS RESEARCH.** An opening is offered to a University Graduate to build up and lead a group to study the more advance aspects of integrated data processing systems for commercial applications. The qualifications sought for this position are, a good general education, an honours degree, preferably in mathematics or electrical engineering, and some previous experience in connection with electronic digital computing, with a leaning towards systems engineering and logical design. A starting salary of up to £1,500, good prospects, pleasant working conditions, and the society of progressive-minded people are offered to the right man. If you would like to know more, send details of your qualifications and experience, mentioning when you would be free for interview, to the Personnel Manager, Powers-Samas Research Establishment, Whyteleafe, Surrey. W 2697

**DEKKO CAMERAS,** 40 Telford Way, East Acton, W.3, have a vacancy for a Technical Engineer with experience of circuitry using thermionic valves and transistors. Applicants with a degree or equivalent will be given preference, good salary paid to the right person. W 1944

**DESIGN AND DEVELOPMENT ENGINEERS** (intermediate) required for the modern laboratory of a progressive engineering company engaged in the advanced development of domestic radio and television. The several vacancies present excellent opportunities to applicants with qualifications to H.N.C. standard who have had previous experience in this field. An attractive salary will be paid to the selected candidates. Eastern suburbs of London. Please reply, giving full details, to Box W 2654.

**DESIGN AND DEVELOPMENT ENGINEERS** (Senior, Intermediate and Junior) required for the modern laboratory of a progressive engineering company engaged in the advanced development of electronics and mechanical engineering in connexion with guided weapon and other applications. The design laboratory is expanding rapidly and, therefore, opportunities exist which give full scope for individual initiative and advancement to applicants who possess H.N.C. and who have also had previous experience in this field. A salary of up to £1,500 per annum will be paid to the selected candidates according to grade. Applications, which will be treated in utmost confidence, should give full details of qualifications and experience and be addressed to Box W 2658.

**DEVELOPMENT ENGINEER** for design of small electrical switches, components and other electro mechanical devices. Please write, advising experience to D.C. Phipps, Director, Crater Products Ltd., St. Johns, Woking. W 1935

**DEVELOPMENT ENGINEER** and several technical assistants required for a design group concerned with a wide range of small transformers of the types used in receiver equipment and electrical appliances. Preference will be given to applicants having experience of this class of work, but young engineers with a sound basic training and a limited experience will be considered and, if successful, will have the opportunity of gaining practical knowledge of design problems met in fulfilling commercial and Services specifications. An attractive salary is offered together with good future prospects. The company's extensive laboratory and production facilities are situated in the eastern suburbs of London. Please reply, giving details of qualifications and experience, to Box W 2655.

**ELECTRICAL ENGINEER** with experience in cable or capacitor development required for research and liaison work. H.N.C. or Degree standard essential. Excellent scope for candidate who prefers problems to routine. Location East London. Write Box W 2682.

**ELECTRICAL AND ELECTRONIC ENGINEERS.** Hilger & Watts Ltd. invite applications from suitably qualified Graduate Engineers willing to assist in the Development of High Voltage Sparking Equipment to be used in the Automatic Analysis of Metals. The successful applicant will need to have a sound knowledge of the techniques of High Voltage and Electronic Design and the ability to negotiate successfully with sub-contractors. The post offers the opportunity of a progressive career with an expanding Company of International reputation. Five-day week, canteen facilities, superannuation scheme. Those interested should write in the first instance stating age and giving full details of education, qualifications and experience, quoting Ref. B.13, to the Personnel Officer, 98 St. Pancras Way, Camden Road, London, N.W.1. W 2698

**ELECTRICAL DEVELOPMENT ENGINEERS** (Grad.I.E.E. or equivalent) required for interesting work on advanced electromechanical systems. Familiarity with basic servomechanism theory and practice, an advantage. Electrical Draughtsman (O.N.C. or equivalent) required to work with development team on preparation of schematic and other diagrams. Successful applicants will work from the design office but will follow work through from laboratory to field trials. Posts are permanent and include participation in voluntary superannuation scheme. Write with details of age, qualifications, experience and salary required to Chief Electrical Engineer, British Manufacture and Research Co. Ltd., Grantham, Lincs, quoting Ref. AWK/MF/EE. W 337

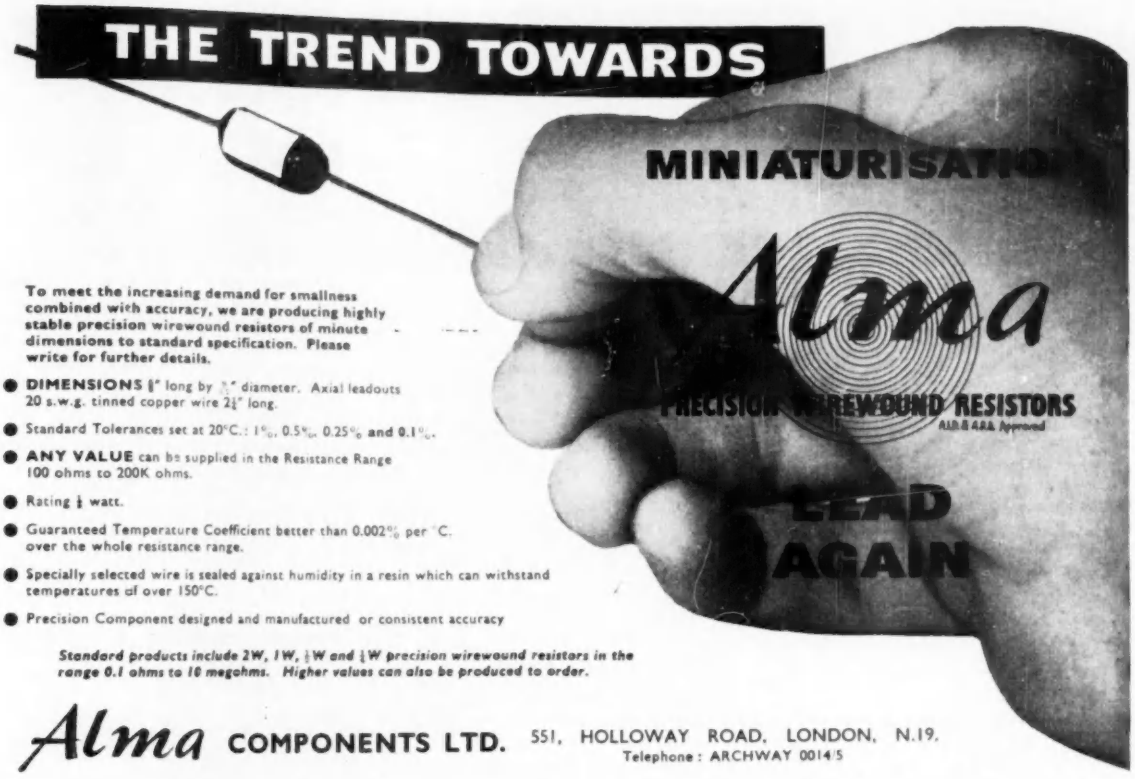
**ELECTRICAL TEST ENGINEER** required for an interesting position in New Laboratory at the Crawley Factory in Sussex of J. Stone (Deptford) Ltd. A Higher National (Electrical) or the equivalent is required, with some Laboratory experience, including the Design of Testing equipment of various kinds. A good salary will be paid to a suitable applicant and assistance will be given towards Housing in the Area. Apply in writing, giving full details of experience, etc., to: Personnel Manager, Gatwick Road, Crawley, Sussex. W 2660

**ELECTRONIC ENGINEER.** Excellent prospects exist in a new group being formed to cater for all technical aspects of electronic equipment being manufactured. This involves development, technical supervision of manufacture and testing, together with the provisioning of a test specification. Candidates should have design experience in one or more of the following: Broad Band Amplifiers, Pulse Techniques, Transformer Design, Microwave Techniques, V.H.F. Techniques, Transistor Circuits. Qualifications should include a Degree or Higher National in Physics or Electrical Engineering, although where candidates have exceptional practical ability, this will be accepted. They should also have the personality necessary to liaise with customers on technical matters. Housing assistance and Superannuation Scheme. Apply: Personnel Manager, The General Electric Co. Ltd., Broad Oak Works, The Airport, Portsmouth. W 2671

**ELECTRONIC ENGINEER.** Qualified to Degree standard, to take charge of instrumentation section of development department. Successful applicant will be responsible for supervising the design, installation and use of test equipment mainly concerned with vehicle braking and suspension systems. Apply by letter giving details of qualifications and experience, to Personnel Manager, Girling Ltd., Kings Road, Tyseley, Birmingham, 11. W 2684.

**CLASSIFIED ADVERTISEMENTS**
*continued on page 4*

# THE TREND TOWARDS




**To meet the increasing demand for smallness combined with accuracy, we are producing highly stable precision wirewound resistors of minute dimensions to standard specification. Please write for further details.**

- **DIMENSIONS** ⅛" long by 1/16" diameter. Axial leadouts 20 s.w.g. tinned copper wire 2½" long.
- Standard Tolerances set at 20°C.: 1%, 0.5%, 0.25% and 0.1%.
- **ANY VALUE** can be supplied in the Resistance Range 100 ohms to 200K ohms.
- Rating ½ watt.
- Guaranteed Temperature Coefficient better than 0.002% per °C. over the whole resistance range.
- Specially selected wire is sealed against humidity in a resin which can withstand temperatures of over 150°C.
- Precision Component designed and manufactured or consistent accuracy

***Standard products include 2W, 1W, ½W and ¼W precision wirewound resistors in the range 0.1 ohms to 10 megohms. Higher values can also be produced to order.***

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**Kidbrooke Park Road, Kidbrooke, S.E.3**
*Telephone: LEE GREEN 2112*

**ELECTRONIC ENGINEER** required for small research department of geophysical consulting concern. Work, of varied and interesting nature, includes low-frequency amplifier design, magnetic recording, transistor circuitry, vibration detection and display, and servo devices. Complete familiarity with two or more of these subjects is a better recommendation than paper qualifications, though H.N.C. or better, specialised in electronics with a background of physics, would be an advantage. Apply Box W 2679.

**ELECTRONIC ENGINEER** required for important work in a small Electronics Laboratory near St. Albans concerned with the design and development of a wide range of equipment used for the instrumentation of aircraft and ground test rigs. Applicants, who should possess a Degree or H.N.C. in electrical engineering or physics, must have a good all-round knowledge of electronics as applied to instrumentation, the field of particular importance including Carrier Amplification and Associated Transducers, Recorders, etc. Full details to Box W 2666.

**ELECTRONICS ENGINEER REQUIRED**, for factory in Surrey Area. First-class experience essential. Highest reference required. Excellent salary and superannuation scheme. Please send details of experience and qualifications to Box W 2662.

**ELECTRONIC ENGINEER** or Physicist experienced in the field of R.F. eddy current heating for post in the field of semiconductors. Experience of high vacuum techniques would be an advantage. Box W 2640.

**ELECTRONIC ENGINEERS.** Two Senior Engineers are required by a leading Electronics Company in West London district. Applicants must have good qualifications (Engineering or Physics Degree standard) and experience in the design and development of radio navigational aids and computer techniques using transistors. Modern laboratories provide excellent conditions. Good and progressive salaries. Pension Scheme. Saturday morning interviews arranged if desired. Please write in full confidence, age, qualifications, experience and salary required to Box W 2532.

**ELECTRONIC TECHNICIANS.** Hilger & Watts Ltd. invite applications from young men for testing and adjusting Electrical instruments. Applicants should be of the standard of G.C.E. "O" Level or O.N.C. in Physics and mathematics and have some background of Electrical or Electronic experience. Higher qualifications would be acceptable for posts of greater responsibility. After a period of training the successful candidates would be required to do part-time Servicing. Five-day week, canteen and Superannuation Scheme. Please apply in writing giving details of age, experience and salary required, quoting reference B7, to Personnel Officer, Hilger & Watts Ltd., 98 St. Pancras Way, Camden Road, London, N.W.1. W 2665

**ELECTRONIC WIRING ASSISTANTS.** Applications are invited from men experienced in Wiring Electronic Equipment, able to work from circuit diagrams and preferably used to Prototype work. Five-day week, canteen and Superannuation Scheme. Please write stating age, experience and salary required quoting Ref. B8 to: The Personnel Officer, Hilger & Watts Ltd., 98 St. Pancras Way, Camden Road, London, N.W.1. W 2661

**ENGINEER REQUIRED** for Test Department of Transformer manufacturing concern. Products handled require a sound basic knowledge of elementary physics (particularly of electricity and magnetism) and a considerable understanding of the technique of electrical measurement. Apply in writing giving full details of education, qualifications and experience to Aero Transformers Ltd., 229 Shenley Road, Borehamwood, Herts. W 1942

**ERICSSON TELEPHONES LTD.** have in their Research Laboratories a number of vacancies for circuit designers and equipment engineers to work on nucleonic instruments and interesting new developments in electronic computing and switching; both senior and junior posts are available. Applicants should have a degree or equivalent plus several years' experience of appropriate work for the senior posts; correspondingly reduced qualifications and experience will be accepted for junior posts. Salaries will be in accordance with age, qualifications and experience. Applications, giving details of age, academic or other training and qualifications, experience and starting salary required, should be sent to the Personnel Officer, Ericsson Telephones Ltd., Beeston, Nottingham. W 197

**ERIE RESISTOR LIMITED** invite applications for the post of correspondence clerk in their main Sales Office in London. Essential qualifications are ability to handle voluminous and varied correspondence, practical technical knowledge, and similar recent experience. Knowledge of export procedure an advantage. Written applications only, stating age, experience and salary required, to Sales Manager, Carlisle Road, The Hyde, London, N.9. W 2691

**ERICSSON TELEPHONES LIMITED,** Instrument Division, have vacancies for Senior and Assistant Electronic Engineers, Mechanical Design Engineers and Laboratory Assistants for interesting work on Industrial and Nucleonic Instruments. Attractive starting salaries and good prospects for advancement will be offered to successful applicants. Write to the Personnel Officer, Ericsson Telephones Limited, Beeston, Nottingham. W 333

**FERGUSON RADIO CORPORATION LIMITED** require Senior Engineer. A high salary is available for a Senior Engineer to work on a variety of projects connected with television. Circuit design experience in at least one of the following subjects is essential. (1) Television tuners. (2) Wide band amplifiers operating at around 40Mc/s. (3) Video frequency pulse amplifiers. (4) Television scanning circuits and components. (5) Colour television systems. (6) Industrial television systems. Applicants should normally possess a good University Degree in Electrical Engineering or A.M.I.E.E., but this requirement will be waived if evidence of satisfactory practical ability is available. Contributory Pension Fund and Life Assurance Scheme. Canteen and welfare facilities. Apply in writing to The Personnel Manager, Ferguson Radio Corporation Ltd., Gt. Cambridge Road, Enfield, Middlesex. W 2652

**METROPOLITAN-VICKERS ELECTRICAL COMPANY LTD.** Development Engineers for Electronics Department. Graduate Engineers or Physicists with two or more years' experience in the field of microwave techniques or microwave receiver systems are required for theoretical or practical work in the development laboratories of the Radar Division. Applicants are requested to write, quoting reference E.10 to: Personnel Manager, Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, 17. W 2669

**ERIE RESISTOR LIMITED** invite applications for the post of technical sales representative for London and the South. Applicants should preferably have had recent similar experience, and must be the holder of the Higher National Certificate in Electrical Engineering, or of some similar qualification, and, above all, must be fully conversant with modern radio and television technology from the manufacturing angle. Applicants must also own a reasonably modern car. Written applications only, stating age, experience, and salary required, to Sales Manager, Carlisle Road, The Hyde, London, N.W.9. W 2690

**I.B.M. (UNITED KINGDOM) LTD.,** Greenock, Electrical Laboratory. Opportunities are available for engineers and technicians in the following fields: (1) Designer of Specialised Test Equipment. (2) Investigation into Component Reliability. Applicants should possess either University Degree or equivalent and have experience in electronic circuitry development or light electrical engineering. The vacant posts offer outstanding opportunities in a modern factory with good conditions. Free Life Insurance Policy and Pension Plan, generous sickness benefit, etc. Salary ranges will be based on qualifications and experience. Applicants should reply in writing stating age, education, experience, etc., to Personnel Manager. W 2680

**INSTRUMENTATION ENGINEER** with electronic background is required for a technical Sales Office. Ability to deal at all levels with complex technical inquiries and contracts. The Company is dealing with pressure, weighing and computing systems. Car owning engineers aged between 25 and 30 invited to apply, salary will depend on qualifications and experience. Apply Transducer Division, J. Langham Thompson Ltd., 88 High Road, Bushey Heath, Herts. Ref. ABC/Sales. W 2681

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**MUIRHEAD & CO. LTD.,** Beckenham, Kent, require Technical Sales Engineer, 28/35, to travel in the Midlands and South Wales areas with short assignments abroad. Applicants should have a sound knowledge of electrical and electronic instruments in the audio-frequency range, also the ability to do routine servicing. Degree or H.N.C. desirable. Full expenses and car provided. Pension Scheme. Apply stating age, salary and experience to Personnel Manager. W 2687

**MAKERS OF T.C.C.** condensers, N. Acton, London, invite application for the positions of Technical Sales Representatives. The situations offer good prospects and are pensionable. Applications, containing details as to age, qualifications, experience and salary required, will be considered in strict confidence. Only first-class men are being entertained—preferably those with experience in the radio and electrical industries. Reply to Sales Director, The Telegraph Condenser Co. Ltd., North Acton, London, W.3. W 2693

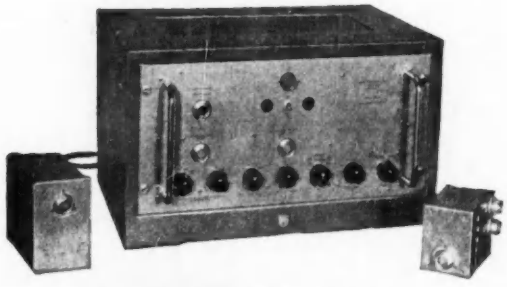
**TECHNICAL ASSISTANTS REQUIRED** for the laboratory of an engineering company situated in the eastern suburbs of London. Applicants should have a minimum qualification of O.N.C. Experience of the light electro-mechanical engineering fields is an advantage but not essential. These several vacancies offer excellent opportunities and a good salary will be paid to the selected candidates. Please reply giving full details of qualifications and experience to Box No. W 2656.

**CLASSIFIED ADVERTISEMENTS**
*continued on page 6*

# EKCO nucleonics & electronics

*information sheet*

**EKCO LINEAR AMPLIFIERS** fulfil the exacting requirements for amplification and pulse-shaping when pulse-counting from ionisation chambers and proportional counters. They are used extensively for research, general counting routine, spectrometry and as part of nuclear reactor start-up systems. These amplifiers operate from A.C. mains and can be supplied for rack mounting, or in instrument cases, as illustrated.



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**Time Constants:** Differentiation and Integration variable between 0.15 microseconds and 1.5 milliseconds.

**Gain:** Variable in 2dB steps from 44dB (×160) to 84 dB (×16,000).

**Gain Stability:** 1% overall with either head amplifier.

**Input Impedance:** 100 ohms or 500,000 ohms and 30pF capacity.

**Output Voltage:** At least 50V positive-going. Hum and noise not more than 1.8V peak-to-peak at full bandwidth.

HEAD AMPLIFIERS

**H.F. Head:** Gain 39dB (×90) constant within 3dB from 50 Kc/s to 500 Kc/s. Input impedance 100 megohms and 10pF capacity.

**L.F. Head:** Gain 39dB (×90) constant within 3dB from 20 c/s to 50 Kc/s. Input impedance 50,000 megohms and 10pF capacity.

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MAIN AMPLIFIER

**Frequency Range:** Gain constant within 3dB from 500 c/s to 2.8 Mc/s.

**Time Constants:** Differentiation variable between 0.08 microseconds and 250 microseconds. Integration variable between 0.08 microseconds and 8 microseconds.

**Gain:** Variable in 2dB steps from 46dB (×200) to 86dB (×20,000).

**Gain Stability:** 0.1% overall with either head amplifier.

**Input Impedance:** 100 ohms.

**Output Voltage:** At least 70V positive-going. Hum not more than 0.25V peak-to-peak at maximum gain.

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**H.F. Head:** Gain adjustable to 12dB (×4) or 34 dB (×50). Input impedance 22 megohms and 10pF capacity.

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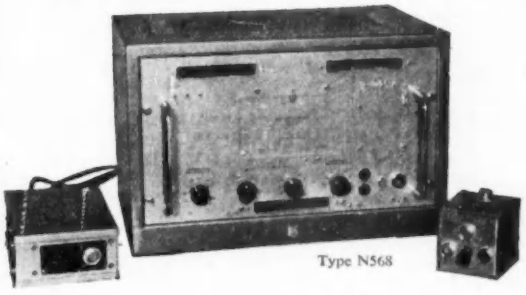

Type N568

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## SITUATIONS VACANT (Cont'd.)

**SENIOR ENGINEER REQUIRED** for electronic components type approval laboratory. Must have good knowledge of R.C.S. and R.I.C. type approval procedure and compilation of reports in a form acceptable to Government Departments. Sound knowledge of mechanical and environmental testing essential. Will be required to act as deputy to Engineer-in-Charge and should be capable of controlling and training junior staff. A generous salary and scope for expansion of interests are offered to suitable qualified applicants. Please reply, giving full particulars of experience and qualifications to Box W 2668.

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**THE NATIONAL RESEARCH DEVELOPMENT CORPORATION** has vacancies in the specialized team it is now expanding for the Development of Electronic Digital Computers and Data Processing Systems of Advanced Design and Performance. An Electrical or Electronic Engineer with digital computer experience is required to maintain liaison with industrial firms with which the Corporation has placed development contracts, and to progress these contracts, and to progress these contracts from the electrical and electronic engineering point of view. Degree or equivalent professional qualifications desirable. A Technical Assistant, preferably with some experience of computer programming, is also required to maintain liaison between the team's programmers and the staff of an important industrial organization with whom the use of a data processing system for production planning and engineering stores inventory is being jointly worked out, and to assist with the overall planning of the programming work, with the maintenance of proper records and documentation and with liaison with the suppliers of the data processing equipment. Organizing ability essential; some technical qualifications and experience in Organization and Methods work desirable. Progressive salary in each case, starting according to qualifications and experience. Contributory Pension Scheme. Five-day week. Canteen facilities. Apply in confidence to N.R.D.C., 1 Tilney Street, London, W.1. W 2683

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**TELEVISION DEVELOPMENT ENGINEERS.** Two senior Engineers are required for the Development Laboratory of an important Company in a West London district. Applicants should hold good academic qualifications and have several years' experience in the development of black and white receivers and some knowledge of colour television. The positions are permanent and pensionable and offer scope for advancement. All applications will be treated in strict confidence and should give full details of experience, qualifications, age, and salary desired to Box W 2592.

**THE PLESSEY COMPANY LIMITED.** Several vacancies exist in the above company for Senior Design Draughtsmen. There is a wide range of work covering electronics and electro-mechanical equipment and a background of design and production of such equipment or of precision mechanisms would be particularly useful. These vacancies carry an attractive salary and long term prospects for the right men. The company operates superannuation and life insurance schemes. Applications, which will be treated in strictest confidence, should be addressed to The Employment Manager, The Plessey Company Limited, Vicarage Lane, Ilford, Essex. W 2674

**TRANSISTOR ENGINEER.** A vacancy exists for an Electronic Engineer at new Research Laboratories in connection with the design and development of novel transistor computing circuits. Qualifications required are a degree, H.N.C. or equivalent and some experience of transistor circuit design. Appls. A. V. Roe & Co., Ltd., Hamworth Lane, Chertsey, Surrey. W 1945

*SITUATIONS VACANT Continued on p. 8*

## SITUATIONS WANTED

**RESIDENT CONTINENTAL REPRESENTATIVE.** Position sought by qualified electronic engineer aged 30, having language proficiency (fluent spoken and written German), sound engineering background and five years' design/development experience with leading electronic manufacturer. Box W 1943.

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**GUARANTEED DELIVERY** from Broxlea Products' new factory at Broxbourne. See page 22. W 2676

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**BOROUGH POLYTECHNIC,** Borough Road, S.E.1. Special Lecture Course on Electron Optics (with particular application to Cathode-Ray Tubes). A course of eleven lectures on the fundamental principles of electron optics will be given on Friday evenings beginning 17 January, 1958. The lectures will be mainly concerned with electron behaviour in Cathode-Ray Tubes and allied apparatus showing how far theoretical considerations influence tube design. The fee for the course will be £1 5s. and the lectures will be given in the evening from 7 to 9 p.m. Further details and application form from the Secretary. W 2670

**BATTERSEA COLLEGE OF TECHNOLOGY.** Electron Tubes and Their Correct Use. A Course of 12 lectures on Wednesday evenings, 7-9, commencing 8th January, 1958. Fee £1. Further details and enrolment forms may be obtained from the Secretary (Electron Tubes Course), Battersea College of Technology, Battersea Park Road, London, S.W.11. W 1938

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**MIDDLESEX COUNTY COUNCIL.** Education Committee, Brunel College of Technology, Woodlands Avenue, Acton, W.3. The following advanced courses in Applied Physics, suitable for graduates or holders of Higher National Certificate, have been arranged. High Vacuum Technology. Twelve-week course on Monday evenings from 6.30 to 9.30 p.m., commencing 6th January 1958. Ultrasonics. Six-week course on Wednesday evenings from 7 to 9 p.m. commencing 12th February 1958. Further particulars may be obtained from the Principal, C. E. Gurr, M.Sc., Ph.D., Secretary to the Education Committee. W 2694

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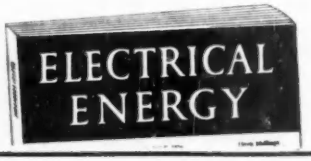


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This Laboratory is newly equipped with tensile, compression and torsional testing machines as well as vibration test equipment. It is intended that Technical Assistants will have responsibility for the operation and maintenance of these sets as well as playing an active part, as members of a team, in the objective work of the Laboratory which will include general mechanical testing and instrumentation work.

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*Application forms and details may be obtained from:—*

**The Personnel Manager,**
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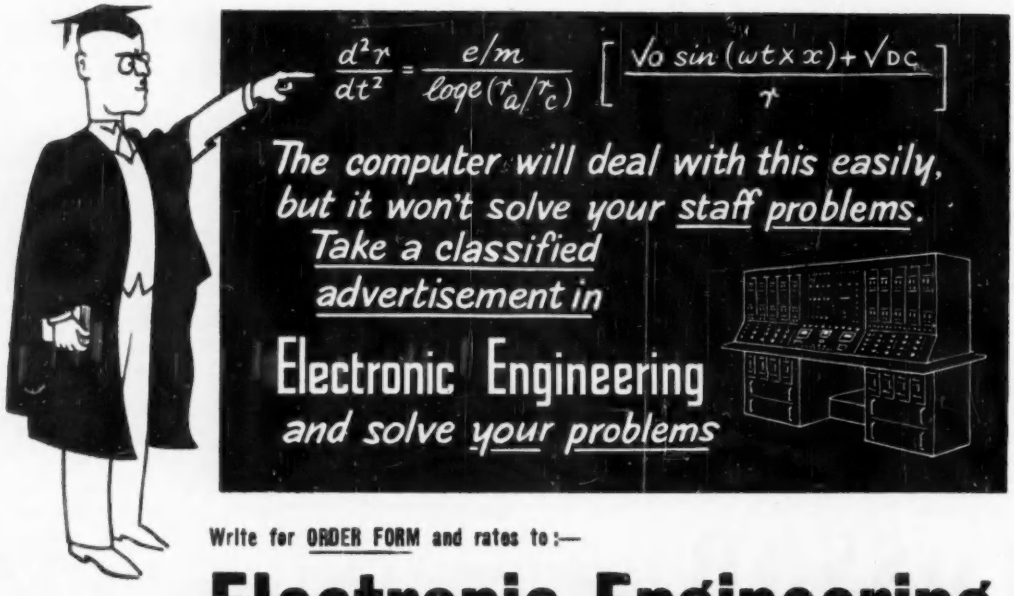
**Strowger Works, Liverpool, 7.**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To be responsible for the functioning of automatic and manual equipment used in quantity production of germanium and silicon transistors. Experience of delicate optical and electro-mechanical control methods would be an advantage.

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Senior positions requiring either experienced electronic engineers or physicists with electronic background, and involving responsibility for the functioning of all electronic and electrical control equipment used in transistor manufacture. Experience in semiconductor development is desirable.

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## DEVELOPMENT ENGINEERS

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## ELECTRONIC PLANNING ENGINEER

whose main responsibility will be the lay-out of circuits designed in our Test Equipment Laboratory for a wide range of test equipment. Knowledge of mechanical design and drawing experience will be required. It is expected that applicants will have had experience on similar work.

A substantial salary will be paid. Please send full details of experience and qualifications to the:-

**Personnel Officer,**
**Ferranti Limited, Ferry Road, Edinburgh 5,**
**quoting Ref. No. 23 EPE.**

## FERRANTI LIMITED

**have**

## IMPORTANT VACANCIES

**in their**

## ELECTRONIC COMPUTER DEPARTMENT

**for**

## SUPERVISING COMPUTER ENGINEERS

**to work on the new MERCURY computer at Harwell.**

Engineers resident in the Oxford area or who would be willing to take up residence in the district are invited to apply for one of these appointments. An essential qualification is a knowledge of electronics up to H.N.C. or equivalent standard, whilst experience of service electronic equipment would be an advantage. Experience of Electronic Computers is not however an essential requirement as successful candidates will be given a period of extended training in the Computer Laboratories. Transport will be provided where necessary for travelling to and from the site. (Ref. CD1.)

Similar appointments are also pending at other locations both in the U.K. and Overseas and applications are invited from suitably qualified and experienced Engineers. (Ref. CD2.)

The above appointments carry excellent salaries with the benefit of a Staff Pension Scheme and a Dependants' Insurance Scheme.

**Forms of application can be obtained from T. J. Lunt, Staff Manager, Ferranti Limited, Hollinwood, Lancs.**
**Please quote Ref. CD1 or CD2.**

JLT GROUP JLT GROUP

## *INSTRUMENTATION*

**— APPOINTMENTS VACANT —**

In order to carry out an interesting expansion programme J. Langham Thompson Ltd. require further staff to increase present departments and to create new teams to handle a wealth of new and interesting products. The activities of the Company encompass the following fields:—

***Circuit Design : Mechanical Sensing Elements : V.H.F. and Microwave Receiver Design : Cameras : Light Electro-Mechanisms : Servo Mechanisms : Data Reduction Systems : Telemetry, Magnetic Amplifiers : Stabilised Power Supplies***

Government and Commercial projects are carried out in our works and laboratories situated in Stanmore (Middx), Bushey and Watford.

**— PERSONNEL REQUIRED —**

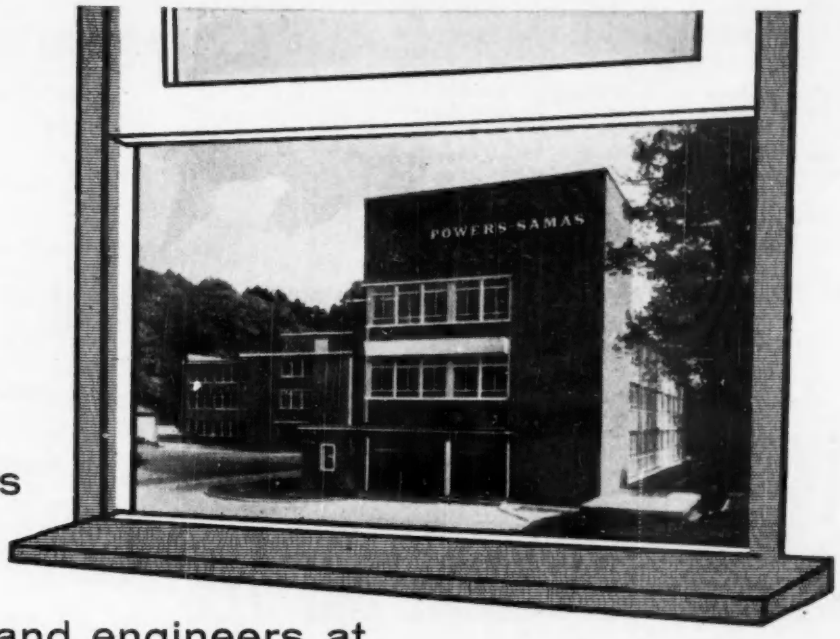
**SENIOR AND JUNIOR ELECTRONIC DEVELOPMENT ENGINEERS**
**SENIOR MECHANICAL DESIGNERS**
**SENIOR AND JUNIOR DRAUGHTSMEN**
**TEST ENGINEERS**
**SENIOR AND JUNIOR FIELD ENGINEERS**
**PROTOTYPE WIREMEN AND INSTRUMENT MAKERS**

The posts require initiative and drive. Prospects of advancement are excellent. Apply in writing stating age, qualifications, experience, and some indication of salary expected, to the

*CHIEF ENGINEER, 2/4 Wigton Gardens, Stanmore, Middlesex.*

**J. LANGHAM THOMPSON LIMITED**

**88 High Road, Bushey Heath, Hertfordshire**




# Opportunities for scientists and engineers at **POWERS-SAMAS** research establishment

The continuing expansion of this leading Company in the accounting machine industry offers exceptional opportunities for scientists and engineers to engage in the absorbing work of designing and developing electronic, electrical and mechanical equipment for the world market.

The vacancies are all for permanent, pensionable staff appointments at the Research Establishment at Whyteleafe, Surrey. Completed in March, 1957, the Establishment is one of the finest and best-equipped in Britain. It is in a most pleasant country setting yet is only some 35 minutes from central London by Southern Region to Whyteleafe South Station.

Generally (and subject to any specific qualifications stated below), applicants should have an engineering degree, H.N.C., O.N.C., or similar qualifications, and previous shop and design experience in the electronic, electrical or mechanical fields. A five-day week is in operation and working conditions and amenities are those to be expected in a modern, well-equipped research establishment.

Applicants should send a brief description of their qualifications and experience to the Personnel Officer at the address shown below.

## openings exist for

### DESIGN

Senior Designers and Draughtsmen with experience in either the mechanical field or the electrical and electronics field, for work on design and development of modern accounting machinery.

### PROJECT ENGINEERING

Men with previous process planning and/or methods engineering experience both electrical and mechanical, for liaison between research, design and production.

### LOGICAL DESIGN

Mathematicians or others with an aptitude for logical design and some knowledge of computer programming for commercial accounting.

### PRODUCT IMPROVEMENT

Senior and junior mechanical engineers with technical qualifications, and design and production experience in light engineering to join teams improving the design and performance of the current ranges of machines. A knowledge of mechanism design using modern techniques, and an open enquiring mind, are essential requirements.

### RESEARCH

Senior and junior research engineers and physicists to engage in applied research in the field of Data Processing. Applicants should have a degree in electrical engineering or physics, or be Corporate or Graduate members of the I.E.E., or Associates or Graduates of the Institute of Physics. Applicants for senior positions should have some experience in digital computing or allied fields. Vacancies also exist for Laboratory Technicians to assist in research and development projects. Applicants should have technical qualifications or experience in electronics or physics.

POWERS-SAMAS ACCOUNTING MACHINES LIMITED, Research Establishment, Whyteleafe, Surrey.

# SERVOMEX

*Servomex are always looking for people of much-above-average ability.*

The following vacancies are a selection

## ELECTRICAL ENGINEER

In the Instrument Development Department. Design experience and a comprehensive grasp of principles are essential. The work will involve electrical and mechanical engineering applied to automatic control systems and electronic instruments.

## PRODUCTION ENGINEER

To take charge of a batch production department. A detailed knowledge of all processes is required, an interest in the latest industrial and management techniques and experience of leadership.

## OPERATIONAL RESEARCH STUDENT

For this post (reserved for a woman) a knowledge of statistical mathematics is needed, with a lively brain, and interest in applying methods of science to industrial problems. Adequate guidance will be provided, but much lonely work with a desk calculator is involved.

*Please write to the Managing Director*

*SERVOMEX CONTROLS LIMITED,*

*Crowborough Hill, Jarvis Brook, Sussex.*

## FERRANTI LTD.

**West Gorton**

**MANCHESTER**

Applications are invited to fill a vacancy for a **TECHNICAL WRITER** which has arisen in the **ELECTRONIC COMPUTER DEPARTMENT.**

Candidates are required to have technical knowledge of Electronics preferably to Higher National Certificate standard, and some experience of technical writing. **TRAINING** will be given to those not having experience of digital computers providing they are suitably qualified.

The appointment is of an interesting nature and will carry an excellent salary. The Company operates a Pension Scheme and a Dependants Insurance Scheme.

Forms of application can be obtained from

**T. J. Lunt, Staff Manager,**
**Hollinwood, Lancs.**

Please quote ref. KL.

## BROOKHIRST SWITCHGEAR LIMITED

**CHESTER**

have vacancies for

## RESEARCH ENGINEERS & PHYSICISTS

in their Research Department

Brookhirst, specialists in electric motor control systems for nearly 60 years and still leading the way in the control of nuclear power, chemical and highly mechanised industrial plant, offer opportunities for engineers and physicists to investigate entirely new control techniques with special reference to magnetic amplifier or transistor circuits. Applicants should possess a 1st or 2nd Class Honours Degree in Electrical Engineering or Physics.

Successful applicants will receive assistance towards the cost of removal, should this be necessary.

The Company operates a Pension Scheme, and in certain cases a transfer of pension contributions can be effected to the scheme.

Apply in writing, giving brief details of age, qualifications and experience, to the

**Personnel Officer, Brookhirst Switchgear Ltd.,**
**Northgate Works, CHESTER**

who will deal with the applications in complete confidence.

## FERRANTI LIMITED, DUNDEE

have the following vacancies:

1. **VALVE ENGINEERS** to assist in the development and production of thermionic valves incorporating challenging new techniques.

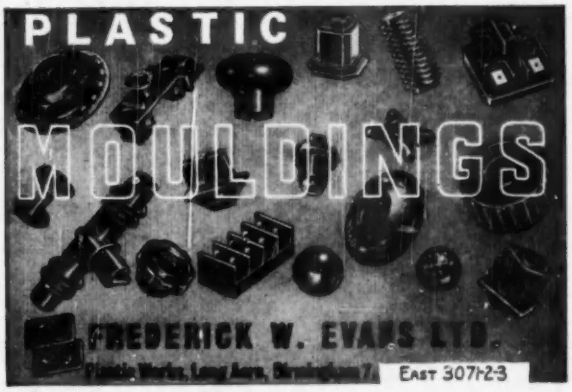
2. **ELECTRONIC ENGINEERS** for development, production and selling aspects of microwave components.

Applicants should possess a degree or equivalent qualifications. The posts offer excellent prospects in a modern factory in pleasant surroundings.

**Attractive salaries commensurate with experience and qualifications will be paid. A staff superannuation scheme is in force.**

*Applications in the first instance to be made to:*

**Capt. T. H. M. Vaughan, R.N. (Rtd.),**
**Ferranti Limited, Ferry Road, Edinburgh, 5**
**quoting Ref.: VL/D 23**




DESIGN • DEVELOPMENT
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## Transformers

***Audio Frequency***
***Current Limiting***
***Modulation***
***Magnetron***
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***Heater***
***Power Packs***
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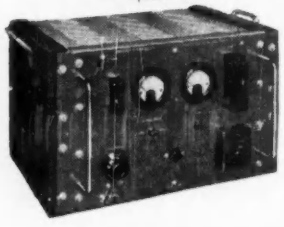
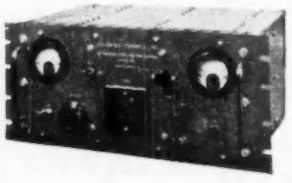
Approved A.I.D. and A.R.B.

**WARDRAY & CO. LIMITED.**
**STANLEY ROAD, LONDON, N.W.9.**
*Telephone: Hendon 9666.*

# EVERYTHING UNDER CONTROL with Servomex A.C. Voltage Stabilisers



*A.C.7 · 0–30 amps, Range minus 20% to plus 10%, 12 volts per second.*



*A.C.2 MkIIB · 0–9 amps, Range minus 17.5% to plus 8.75%, 15 volts per second (A.C.2 MkIIA is identical except there are no meters).*

which could help YOUR electrical measuring gear to work at its best . . . the cost, at 5d. to 1/- per watt is trifling . . . may we send details ? a scribbled name and address on this page will suffice.

*P.S.—87% of our orders are repeats.*

**SERVOMEX**

**Servomex** Controls Limited, Crowborough Hill, Jarvis Brook, Sussex.
*Crowborough 1247.*

INSTRUMENTS FOR RESEARCH AND PRODUCTION

## Automatic Recording of Harmonics

by means of

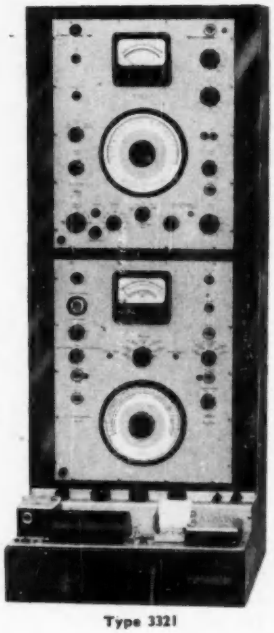
# A. F. RESPONSE AND SPECTRUM RECORDER

### TYPE 3321

The harmonics produced in any electrical or electro-acoustical system may be recorded with this set-up. In the example shown, the 3321 is applied to the recording of harmonics produced in a complete hearing aid device. The measurements are **recorded automatically on pre-printed, frequency calibrated recording paper.**

An example of the frequency-amplitude diagram, obtained from measurements during which the sound pressure in front of the hearing aid was kept constant, is also shown.

The A.F. Response and Spectrum-Recorder is an extremely versatile instrument, which consists of the Beat Frequency Oscillator, Type 1014, the Audio Frequency Spectrometer, Type 2109, and the Level Recorder, Type 2304: all instruments being mechanically coupled together.



Type 3321

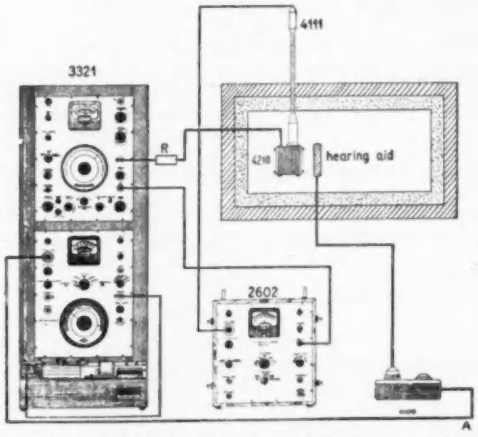
The **Oscillator** is equipped with **frequency modulation**, the frequency and modulation swing of which may be varied.

Provision is made for **external modulation.**

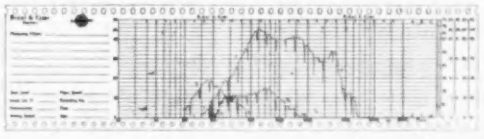
Furthermore, an **automatic output regulator** offers the possibility of keeping the voltage, current or sound pressure constant during measurements when the Oscillator is used as power source. The regulation speed is variable in steps.

The **Spectrometer** contains 27 one-third octave band-pass filters and 3 weighting networks for **sound level measurements.**

Furthermore, it can be switched to have a linear frequency response, thus operating as an ordinary **audio frequency amplifier** or **voltmeter.**




Ten different speeds for the recording paper and 9 different speeds for the frequency sweep make possible a large number of combinations.



For obtaining polar diagrams the **Polar Diagram Recorder,** Type 2370, can be directly attached to the **Level Recorder.**

The instruments contained in the A.F. Response and Spectrum Recorder may be used separately or in any combination.

**For further information concerning this and other instruments apply to:**

B K

**Brüel & Kjær**

Adr.: NÆRUM, DENMARK · Teleph.: NÆRUM 500 · Cable: BRUKJA, COPENHAGEN

**SALES AND SERVICE: B & K Laboratories, 57 Union Street, LONDON S. E. 1.**

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# CATHODEON

## Miniature Crystal Oven

This miniature oven has been designed specifically for accurate temperature control of Ministry Style "D" (Cathodeon Type 2M) Crystal Units. It is particularly recommended where the requirement is for a frequency stability better than .0002% over a wide range of ambient temperatures.

**Centre tapped heater** for 6.3 or 12.6 volt supplies.

**Current consumption** 0.73 amp. at 6.3 volt.

**Temperature differential** ±2°C within a temperature range 75°C to 85°C.

**Temperature control** within the ambient range—20°C to +70°C.

**Heating time** less than 5 minutes from ambient temperature to 85°C.

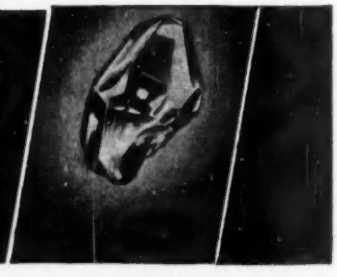
**Precision bi-metallic contacts** with provision for On/Off indicating lamp.

**Low loss Mycalon base.**

**Weight** 1½ oz. (43 grammes).

**Overall Dimensions** 1¼" x 13/16" x 2⅝" long (3.2 x 2.0 x 6.6 cm.).

**CATHODEON CRYSTALS LIMITED**
**LINTON CAMBRIDGESHIRE**
**TELEPHONE LINTON 501 (3 lines)**



# A COMPREHENSIVE RANGE OF REGULATED OPEN CHASSIS SUPPLIES

***WITH THE FOLLOWING FEATURES · ·***

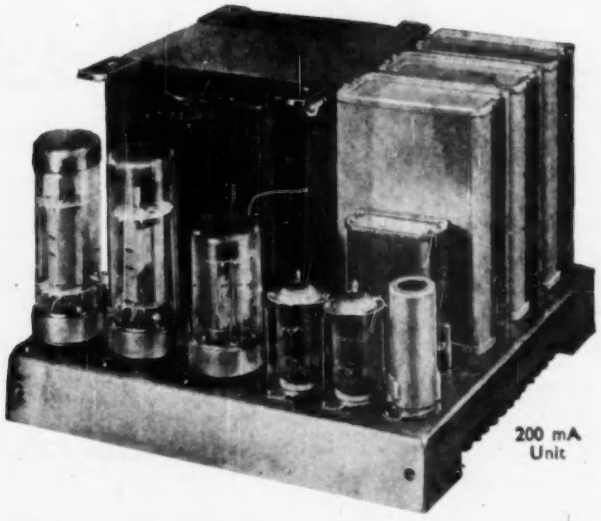
**OMISSION OF CHOKE**—resulting in ability to operate down to zero current with complete stability—freedom from transient voltage surges due to shock loading—miniaturised units.

**CONSERVATIVE RATING**—all units are guaranteed to maintain stability for ±10% mains variation. The majority will operate to at least −15%.

**LONG LIFE**—Inter Services approved paper condensers used throughout. Adequate derating of series valves where more than one is used.

**FREEDOM FROM DRIFT**—exclusive use of double triode difference amplifiers in feedback circuit ensures long term stability.

**IMPEDANCE CONTROL**—a preset potentiometer allows for smooth adjustment of impedance from positive to negative values. Can be used to offset the impedance of a series milliammeter.



200 mA Unit

| MODEL | D.C. OUTPUT | | A.C. OUTPUTS | EFFECTIVE RESISTANCE | VOLTAGE STABILITY | RIPPLE | SIZE | PRICE Ex-works |
|---|---|---|---|---|---|---|---|---|
| | VOLTS | CURRENT | | | | | | |
| M23 | ±150V | 0-50mA | 6·3V2A & 6·3VIA | <0·1Ω | <0·02% | <1mV | 6"×5½"×5¾"ht. | £30-0-0 |
| M23A | ±200V | 0-50mA | 6·3V2A & 6·3VIA | <0·1Ω | <0·02% | <1mV | 6"×5½"×5¾"ht. | £30-0-0 |
| M33 | ±250V | 0-50mA | 6·3V2A & 6·3VIA | <0·1Ω | <0·02% | <1mV | 6"×5½"×5¾"ht. | £27-10-0 |
| M24 | ±150V | 0-100mA | 2×6.3V 3A C.T. | <0·1Ω | <0·02% | <1mV | 7⅜"×6¾"×6½"ht. | £33-10-0 |
| M24A | ±200V | 0-100mA | 2×6·3V 3A C.T. | <0·1Ω | <0·02% | <1mV | 7⅜"×6¾"×6½"ht. | £33-10-0 |
| M34 | ±250V | 0-100mA | 2×6·3V 3A | <0·1Ω | <0·02% | <1mV | 7⅜"×6¾"×6½"ht. | £33-10-0 |
| M34A | ±300V | 0-100mA | 2×6·3V 3A | <0·1Ω | <0·02% | <1mV | 7⅜"×6¾"×6½"ht. | £33-10-0 |
| M25 | ±150V | 0-200mA | 2×6·3V 3A C.T. | <0·1Ω | <0·02% | <1mV | 8¾"×8½"×5¾"ht. | £52-10-0 |
| M25A | ±200V | 0-200mA | 2×6·3V 3A C.T. | <0·1Ω | <0·02% | <1mV | 8¾"×8½"×5¾"ht. | £52-10-0 |
| M35 | ±250V | 0-200mA | 2×6·3V 3A | <0·1Ω | <0·02% | <1mV | 8¾"×8½"×5¾"ht. | £52-10-0 |
| M35A | ±300V | 0-200mA | 2×6·3V 3A | <0·1Ω | <0·02% | <1mV | 8¾"×8½"×5¾"ht. | £52-10-0 |
| M36S | ±250V | 0-500mA | 2×6·3V 5A | <0·1Ω | <0·02% | <1mV | 14"×11½"×8¼"ht. | £88-0-0 |
| M36SA | ±300V | 0-500mA | 2×6·3V 5A | <0·1Ω | <0·02% | <1mV | 14"×11½"×8¼"ht. | £88-0-0 |
| M38 | ±250V | 0-350mA | 2×6·3V 5A | <0·1Ω | <0·02% | <1mV | 13½"×8¾"×6¾"ht. | £66-0-0 |
| M38A | ±300V | 0-350mA | 2×6·3V 5A | <0·1Ω | <0·02% | <1mV | 13½"×8¾"×6¾"ht. | £66-0-0 |

***ALSO***

**TYPES M36/36A ±250/300V at 0.5A**
**M37/37A ±250/300V at 1.0A**
With 19" panels for rack mounting.

***AND***

**A RANGE OF TRANSISTOR STABILISED SUPPLIES**
for transistor applications.

*made and guaranteed by :*

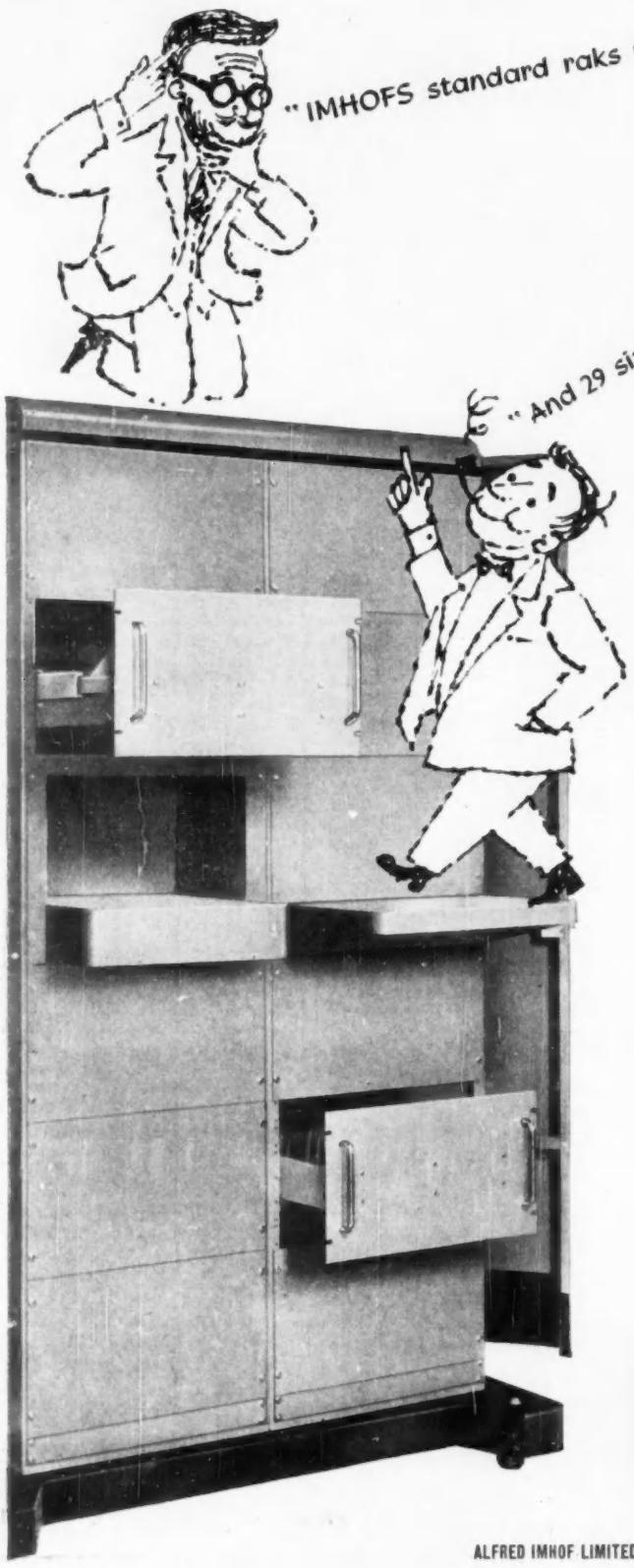
# ROBAND

## ELECTRONICS LIMITED

**33 Mountgrove Road, Highbury, N.5.**

**Telephone: CANonbury 4581**

LG8




DESIGNING equipment for rak assembly? Install it in Imhofs standard raks. Strong and beautifully finished, these precision-built metal cabinets protect and enhance equipment, and save you all the trouble and expense of construction. They also allow for great flexibility in your production—you can buy just as many as you *want* when you want them. Write now for catalogues and full details of Imhofs specialist service—it includes standard instrument cases, consoles, the Imlok make-it-yourself cabinet construction system, and any metal housing made to order.

**QUANTITY DELIVERY IN 7 DAYS!**

**Order as you want them—delivery of any size or number ex stock in 7 days. Even sooner if really necessary! Special terms for quantity orders. 29 sizes with one or more bays give you wide choice.**

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*Family men, enlisting the aid of their offspring, will probably be rewarded with ADDLIRGE or even DIDLARGE. Astute Buyers will, however, know that the name synonymous with Plastics is* ALDRIDGE!

ALDRIDGE is a comparatively new name in the moulded plastics field. It is a vigorous Company enjoying the benefits of the most modern factory and plant, and administered and staffed by men whose knowledge and experience of plastics mouldings extends back to the beginning of the Industry itself. ALDRIDGE make all types of thermo-setting and thermo-plastic mouldings for the leading names in many Industries . . . . . ALDRIDGE is ready to serve YOU!

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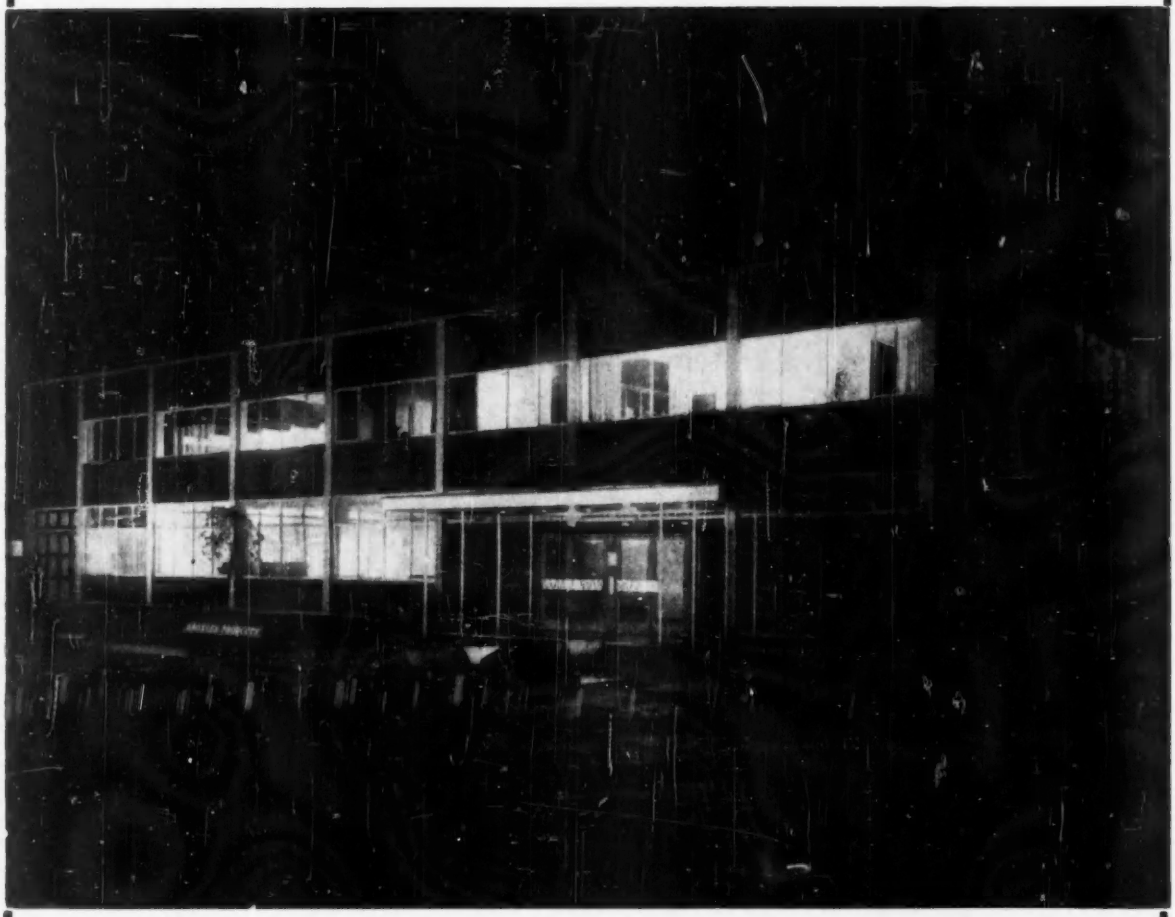
L.G.16.

# Another year...

*We used this flood-lit view of our new works to send seasonal greetings to all our friends. May we now wish all readers of "Electronic Engineering" good fortune and a solution to their (electronic) production problems in 1958!*



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*A.I.D. approved sub-contractors*

**PARK LANE, BROXBOURNE, HERTFORDSHIRE**

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## BRITAIN'S FOREMOST DESIGNERS

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# PRECISION RELAYS

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Relays
is always available for
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SPECIAL TYPES CAN BE DESIGNED
TO SUIT YOUR NEEDS

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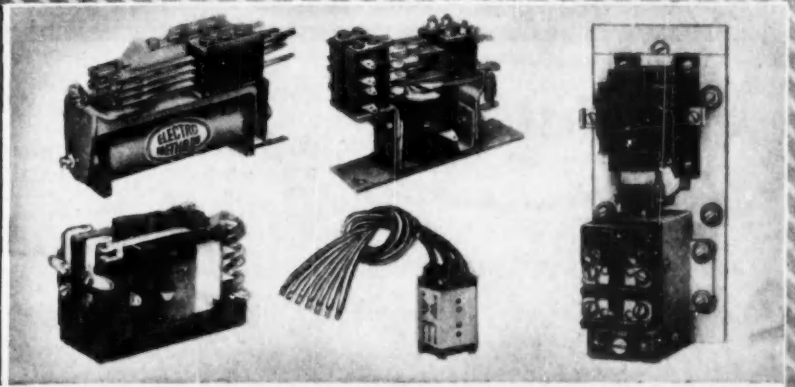
*Full technical data*
*and illustrated leaflets promptly*
*forwarded on request*

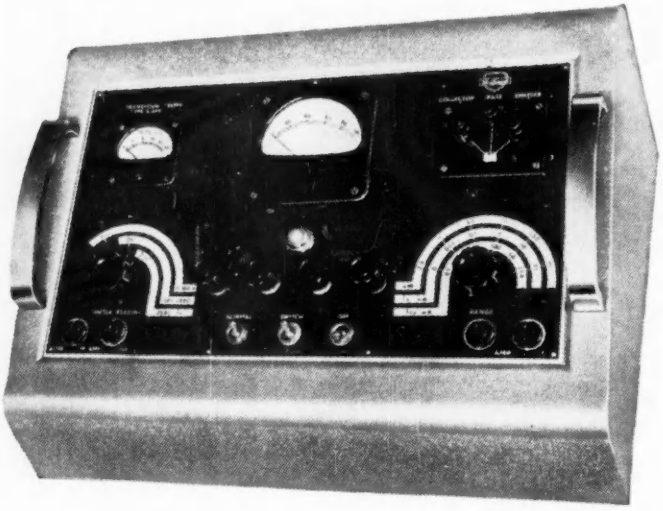


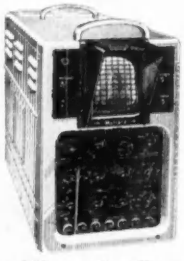
ELECTRO METHODS LTD. 17-41 CAXTON WAY, STEVENAGE, HERTS. Phone: STEVENAGE 780

# Mullard Instruments for the laboratory

*Transistor Tester*
L264

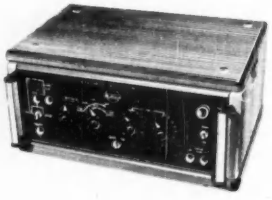
The Mullard Transistor Tester has been developed to provide a rapid means of checking general characteristics and ascertaining if a transistor has been damaged in circuit. Facilities for measuring the important parameters, $\alpha$, base-collector short-circuit current gain, as well as $I_{co}$ and the collector turnover voltage are provided. Although designed as a simple testing unit, it has an accuracy of $\pm 5\%$.





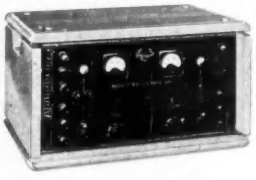
*Dual Trace Oscilloscope*
L101/2

This high grade, general purpose instrument incorporates two identical amplifiers with sensitivities of 20mV/cm over a bandwidth of 4 Mc/s. Calibration accuracies are voltage $\pm 5\%$, and time $\pm 10\%$ by null methods. The time base may be free running or triggered, and sweep speeds are from 0.1 $\mu$s/cm to 10 ms/cm.



*Television Line Selector*
L196

The L.196 enables any normally triggered oscilloscope to give a jitter-free display of one or more lines from a television video signal. It can be used on transmitter and receiver circuits to display depth of modulation, d.c. levels, bandwidth, blanking, synchronizing pulses and for the examination of similar waveforms in detail.



*Regulated Voltage Unit*
L153

This is a general purpose laboratory unit which provides a stable low impedance d.c. supply which can be continuously varied between 0 and 300V positive and negative at up to 300mA. Two 4 amp a.c. supplies at 6.3V tapped at 4V are also incorporated and an unregulated e.h.t. supply of 1.2kV at 2mA.

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Specialised Electronic Equipment

Mullard

MULLARD LIMITED · EQUIPMENT DIVISION · MULLARD HOUSE
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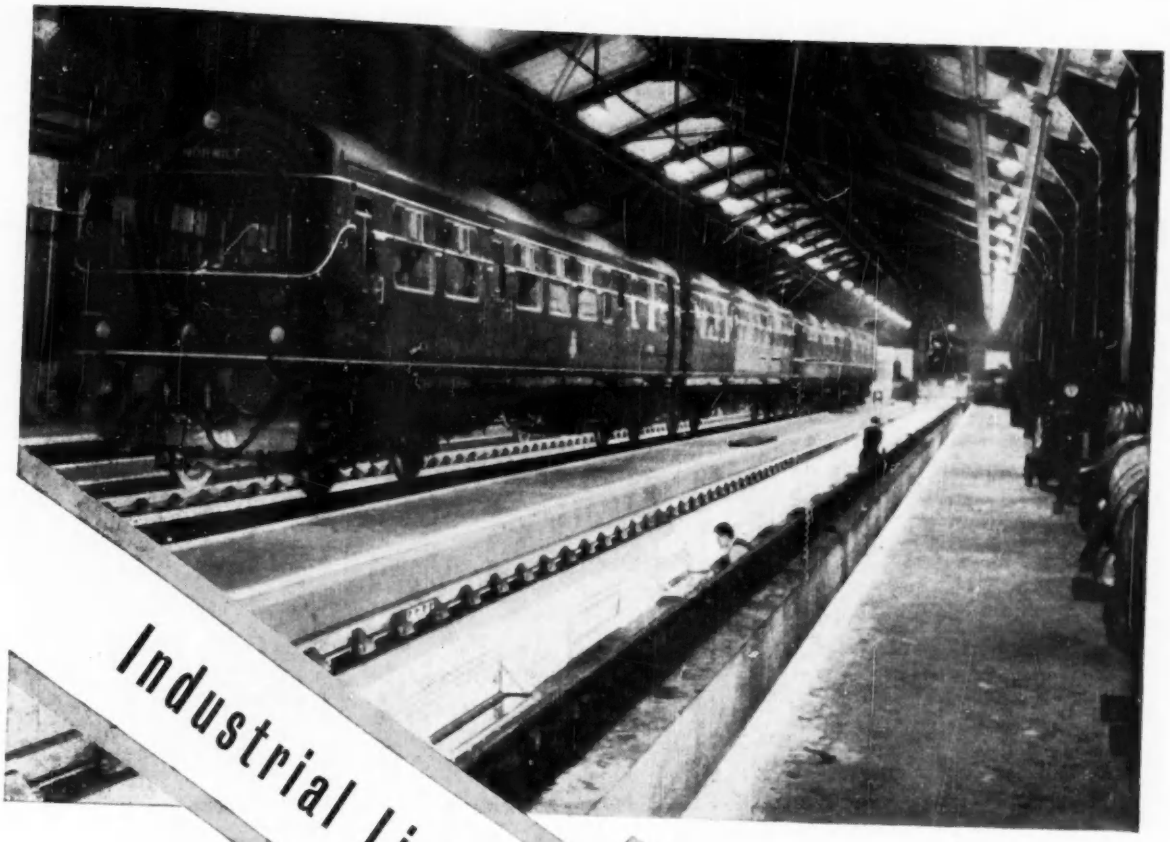
ME600



*British Railways, Eastern Region*
*Norwich Diesel Depot*

# Industrial Lighting by FALKS

FALKS Lighting Engineers offer you the following service:—

- Study of your particular lighting problem either at your works or from plans.
- Recommendation of the most suitable method of lighting and type of lighting fitting.
- Preparation for your approval of lighting lay-out plans and estimates.

**INDUSTRIAL LIGHTING IS A MATTER FOR THE SPECIALIST**

*Catalogues of tungsten and fluorescent lighting fittings on request.*

We design and manufacture electric lighting fittings for all industrial requirements

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**91 FARRINGDON ROAD LONDON EC1 and branches · Telephone: HOL 7654**

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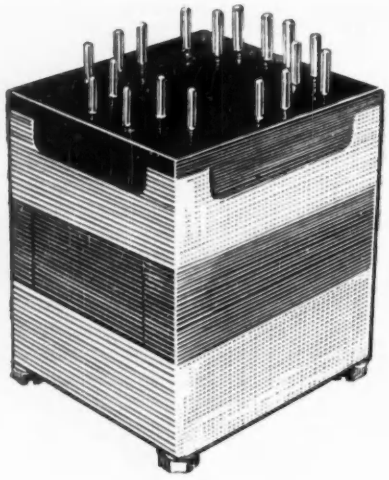
*AP41*



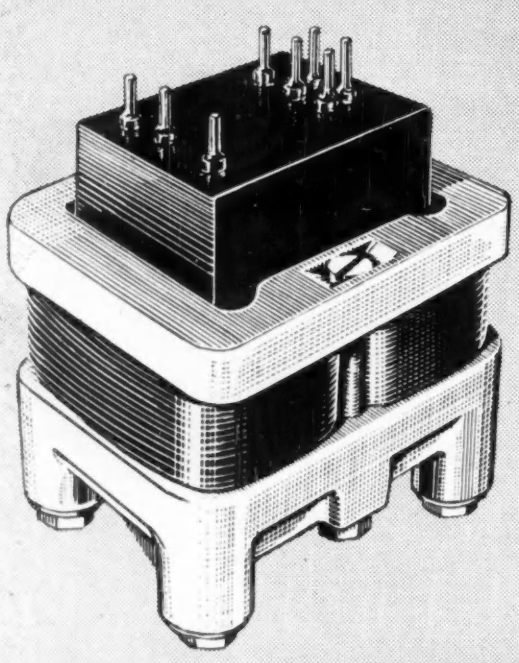
*R120 and R130 laminated series.*

# FORTH SERIES

## TRANSFORMERS AND CHOKES

***smaller in size — lighter in weight***

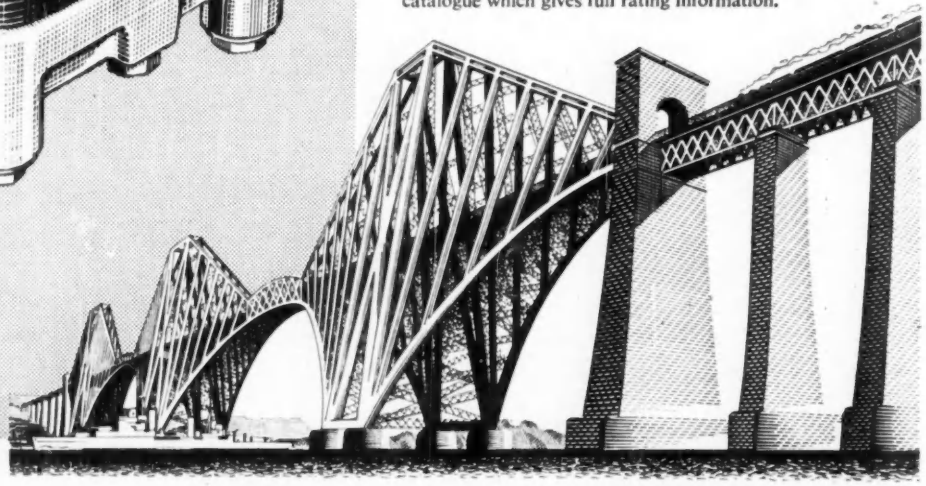
*R200 'C' Core series.*



# FERRANTI

The new range of Ferranti Resin Cast Transformers and Chokes has been named after this famous Scottish landmark which represented a remarkable advance in engineering design when it was constructed over 60 years ago. To-day, the new techniques in manufacture and construction of 'C' Core Transformers have enabled Ferranti Ltd. to make a significant contribution to Electronic Engineering.

The Forth series components will have particular appeal to designers of airborne equipment since savings in weight and volume of up to one-third can be achieved over the resin cast and oil-filled units now available. Moreover, the quality requirements of the Joint Service Specification RCS.214 are met in every respect. Please write for a catalogue which gives full rating information.



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ES/T41

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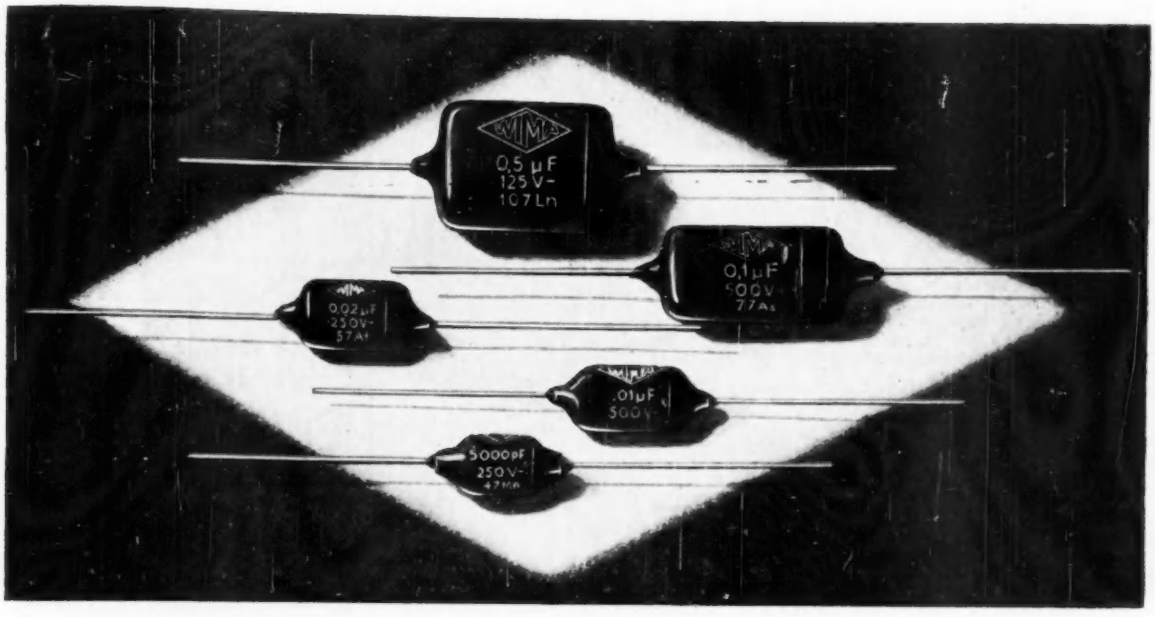



## TROPYDUR WIMA CONDENSERS

*"The only condenser flattered by imitations"*

Don't let lack of condensers hold up production. PROMPT AND RELIABLE DELIVERY of WIMA Tropydur Condensers will speed completion of your orders!

The ideal flat-oval dimensions of these paper and foil capacitors enables them to be used to advantage in restricted spaces. Terminal wire points are completely sealed off by our special hot dip process which ensures the highest operational standards, and makes them particularly suitable for all tropical and export equipment.

Wima Tropydur Condensers provide the finest service to the engineer today and provide maximum reliability and performance.

**NEW REDUCED SIZES PARTICULARLY SUITABLE FOR PRINTED CIRCUITRY**

| | | | |
|---|---|---|---|
| Capacity range : | 50pF to 1 mfd. | Temperature Range: | −20° C to +90° C |
| Tolerance: | | Test Voltage: | 5 seconds at three times the rated voltage. 1 minute at twice the rated voltage. |
| STANDARD : | <0.1 mfd. ±20% >0.1 mfd. ± 10% | | |
| SPECIAL TO : | ±5% | | |

Full Technical Specifications and Prices from **SOLE AGENTS**

**W. S. WAYLETT & COMPANY LTD.,**

**EMPIRE BUILDINGS, DUKE ST. HILL, LONDON, S.E.1. Tel: HOP 5055/6**

# SOLARTRON HOME AND EXPORT PRICE LIST

*Effective from 1st January, 1958*

| DESCRIPTION | TYPE | PRICE ex works, unpacked |
|---|---|---|
| Gyro Response Test Console | JY. 747 | Price on application |
| Servotest Console | JY. 672 | Price on application |
| Ignition Delay Meter | ECS. 1 | £220 |
| Laboratory Amplifier | AWS. 51A | £130 |
| Wide-Band Power Amplifier | AWS. 53 | £175 |
| Pulse Generator | OPS. 100C | £130 |
| L.F. Decade Oscillator | OS. 103.2 | £640 |
| Transfer Function Analyser | OS. 103.2/VP. 253.2 | £1,300 |
| Regulated Power Supply | SRS. 151A | £115 |
| Twin Regulated Power Supply | SRS. 152 | £190 |
| Single Regulated Power Supply | SRS. 152A | £100 |
| Solartron Vari-Pack | SRS. 153.2 | £50 |
| Power Supply Sub-Unit | SRS. 156 | £35* |
| Wide-Band Attenuator, 600 Ohm | AT. 201 | £25 |
| Calibrating Unit | AT. 203 | £175 |
| Resolved Components Indicator | VP. 250 | £475 |
| Feedback Voltmeter | VF. 252 | £175 |
| Resolved Components Indicator | VP. 253.2 | £660 |
| High Frequency Amplifier | CA. 411 | £70 |
| Square Wave Generator | GO. 511 | £95 |
| Standing Wave Ratio Indicator | CA. 512 | £190 |
| Solarscope | CD. 513.2 | £220 |
| Power Supply Sub-Unit | AS. 516 | £35* |
| Power Supply Sub-Unit | AS. 517 | £35* |
| Oscilloscope | CD. 518 | £225 |
| Direct Reading T.M.S. | BM. 519 | £220 |
| Solarscope | CD. 523S2 | £265 |
| T.F.A. Carrier Convertor | JX. 541 | £300 |
| Wide Range Oscillator | CO. 546 | £135 |
| Synchrotest | JM. 555 | £375 |
| Solarscope | AD. 557 | £275 |
| Wide-Band Attenuator, 75 Ohm | CR. 561 | £30 |
| Klystron Power Supply | AS. 562 | £175 |
| Servo Test Set | JX. 563 | £450 |
| 2-Phase L.F. Oscillator | BO. 567 | £195 |
| Oscilloscope | CD. 568 | £210 |
| Mechanical Reference Generator | JX. 603 | £375 |
| 800 c/s Selective Amplifier | BA. 604 | £450 |
| Oscilloscope Probe | CX. 606 | £5 |
| Sub-Sonic Power Amplifier | JX. 612 | £255 |
| Power Supply Sub-Unit | AS. 616 | £180* |
| Power Supply Sub-Unit | AS. 619 | £60* |
| Computer Amplifier | AA. 621.2 | £50 |
| Computer Amplifier | AA. 622.2 | £60 |
| Carrier Convertor | JX. 641 | £300 |
| Measuring Solarscope | CD. 643 | £490 |
| Double-Beam Solarscope | CD. 711 | £320 |
| Oscilloscope | CD. 715 | £460 |
| Oscilloscope Trolley | MX. 719 | £25 |
| Crossed-Field Multiplier | TA. 721 | £295† |
| Heater Supply Unit | TS. 722.2 | £24 |
| Ventilation Unit | TX. 724 | £3 |
| Computer Servo Multiplier | TJ. 725 | — |
| Linear Computing Unit | TR. 729.2 | £75† |
| T.F.A. Reference Resolver | JX. 746 | £295 |
| Power Supply Sub-Unit | AS. 754 | £60* |
| Regulated Power Supply | AS. 755 | £115* |
| 100V. Reference Supply | AS. 756.2 | £325 |
| Linear Computing Unit Racking | TX. 790.2 | £30 |
| Amplifier Racking | TX. 791.2 | £30 |
| Computer Control Panel | TC. 792 | £60 |
| Computer Supply Distribution Unit | TS. 793 | £90 |
| Resistance Unit | TR. 794.2 | £20 |
| Solarscope | CD. 814 | £115 |

The prices on this list are net, ex works, unpacked. 2½% discount for cash within 10 days.

* Quantity Discounts Applicable. † Provisional Price.

*This cancels all previous price lists*

**THE SOLARTRON ELECTRONIC GROUP LTD.**

THAMES DITTON · SURREY · Tel.: EMBerbrook 5522

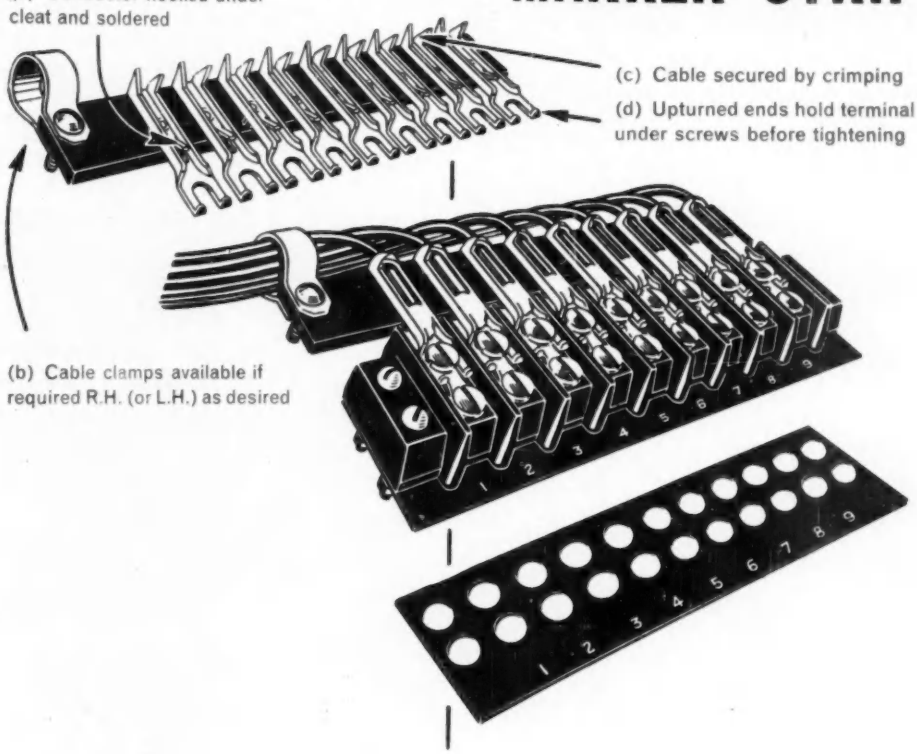
# CINCH

## BARRIER TERMINAL, FANNING AND MARKER STRIPS

(a) Conductor hooked under cleat and soldered

(c) Cable secured by crimping

(d) Upturned ends hold terminal under screws before tightening




(b) Cable clamps available if required R.H. (or L.H.) as desired

'Standard' series are available with various types of terminals, up to 21 way—'Miniature' series up to 12 way. Insulating materials phenolic or 'Mikacin' as specified.

**CARR FASTENER COMPANY LTD**
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Smee's 115

# HYPREZ
## DIAMOND COMPOUND

GIVES
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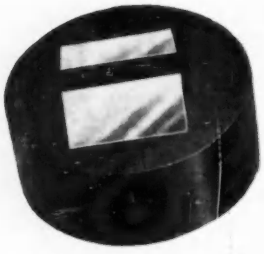
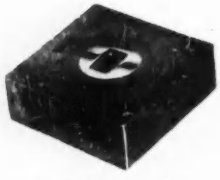
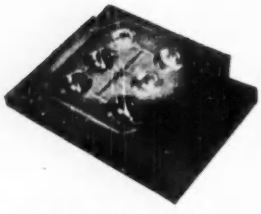
*Some typical applications:*



*METALLURGICAL SPECIMENS*



*EXTRUSION DIES*



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**HYPREZ** is the most up-to-date method for **economic fine-grinding, lapping and polishing,** of steel, stainless steel, cast iron, non-ferrous metals, chrome-plate, stellite, tungsten-carbide, boron-carbide, sapphire, quartz, ceramics, etc.

It has been developed to impart the very finest degree of surface finish to a variety of materials and is currently employed in the finishing of **metallurgical specimens, plastic moulds, tungsten-carbide dies** (i.e. drawing, extrusion, forming and cold-heading dies), **cutting tools, die casting cavities, instrument bearings and pivots, etc.** The hardness of the diamond particles makes it suitable for use on the hardest of metals, for fine grinding, lapping and polishing.

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# THE VALVES FOR J BAND OPERATION

## 'ENGLISH ELECTRIC'

**MAGNETRON TYPE M555**

This is a new packaged magnetron for pulse operation in J Band with a peak input power rating of 240 kW. Particular care has been taken to produce a compact, rugged valve for air-borne applications.

**THE M555**

can be supplied for fixed frequencies within the range 14,000 to 16,500 Mc/s.

**KLYSTRON TYPE K343**

This is a low voltage reflex klystron for J Band operation with a minimum power output of 20 mW at 350 volts. The moulded base and flying leads specially commend it for high altitude operation. It has mechanical tuning covering the range 12,000 to 14,500 Mc/s.

**KLYSTRON TYPE K346**

This is generally similar to type K343 with mechanical tuning from 14,500 to 17,000 Mc/s.

**Both these klystrons, which may be used in conjunction with the M555 or in other J Band applications, have 30 to 80 Mc/s electronic tuning. The output connections are American type UG419/U feeding into No. 18 Waveguide.**

**ENGLISH ELECTRIC VALVE CO. LTD.** *Chelmsford, England*
*Telephone: Chelmsford 3491*

APP85

# The TOUGHEST component test




***will not change the characteristics of the***

## GD 85 WR

### MINIATURE RUGGEDIZED REFERENCE TUBE

Specially constructed for military and commercial service where tubes are to be subjected to severe shock and thermal extremes, this new tube will continue to operate satisfactorily beyond the point which is customarily associated with conventional tube structures.

BRIEF DATA

| | | | |
|---|---|---|---|
| Nom. stabilized voltage | 85V | Shock: | 5 g continuously |
| Striking voltage (total darkness or light) | 125V max. | | 20 g short durations |
| Current range | 500μA to 5·0mA | | 750 g impact |
| Max. Incremental resistance | <1000Ω | Temperature Range: | −60°C to +90°C |

*For full information write to:* Technical Services Dept.

# ERICSSON

TUBE DIVISION

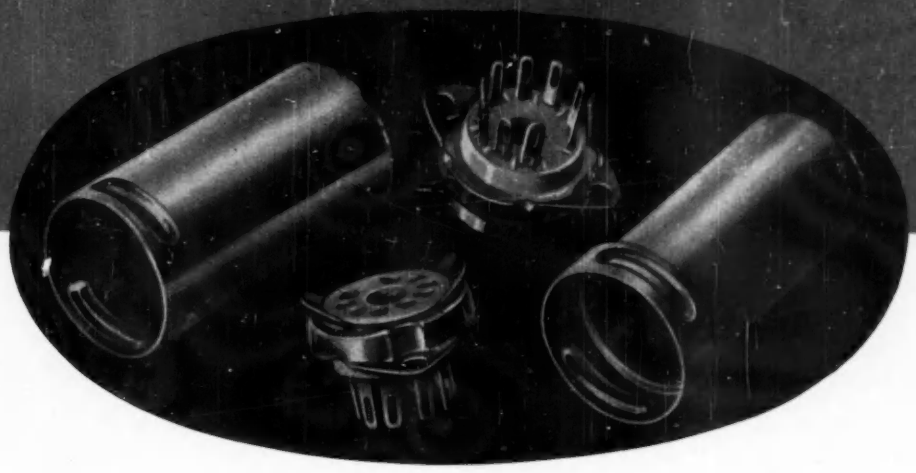
BEESTON, NOTTINGHAM.

ERICSSON TELEPHONES LTD., HEAD OFFICE, 22 LINCOLN'S INN FIELDS, LONDON, W.C.2.

*Originators and Sole Manufacturers of the Dekatron Cold-Cathode Scaling Tube.*

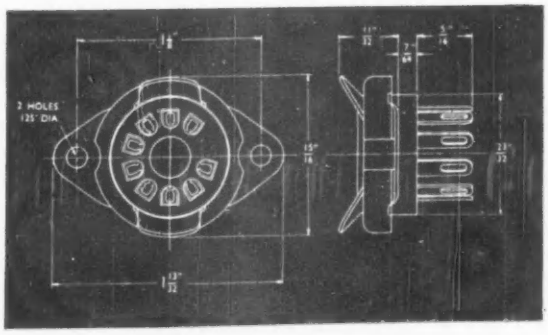
813

# A NEW APPROACH TO VALVE HOLDERS AND SCREENING



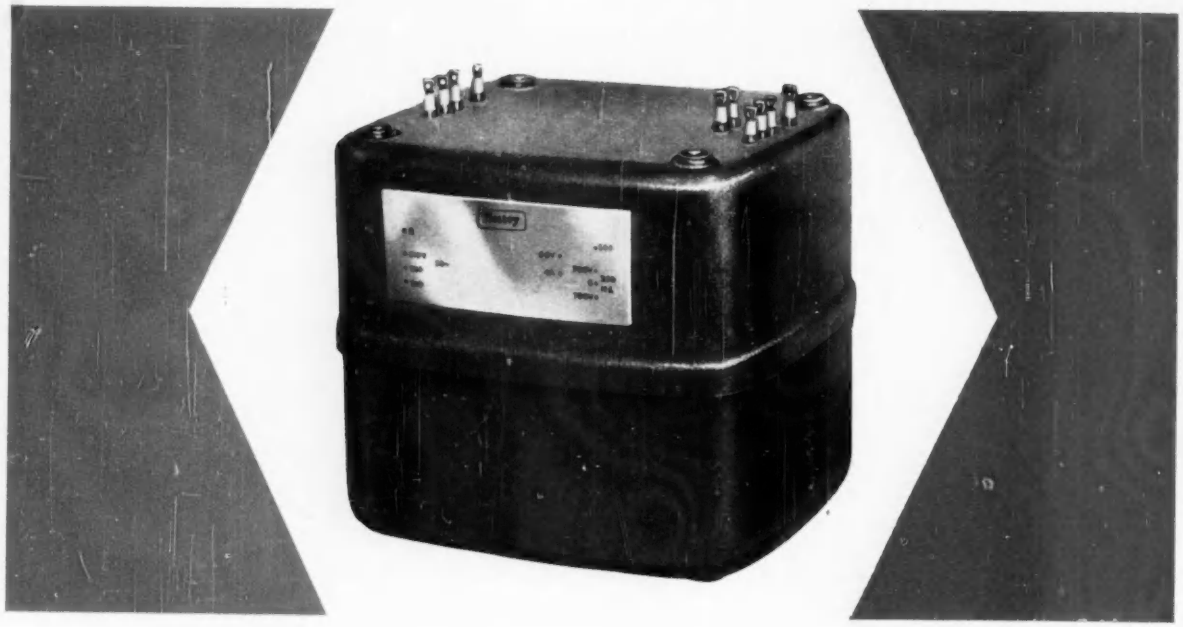
## The Universal B9a Ceramic Valveholder

With great advances being made in all branches of the industry, Brayhead (Ascot) Limited keep step with their latest contribution, the Universal Ceramic B9a Valveholder and screening cans.
This valveholder is the result of extensive research into the requirements of the Radio and Television industry and fills a long felt gap for a valveholder with removable and replaceable contacts but which requires no wiring jig during assembly. The contacts can be specified in either spring quality brass, phosphor bronze or beryllium copper with a tinned or silverplate finish. They can be bent over without affecting contact alignment, and soldered directly on to the chassis. The moulding is formed of silicone treated ceramic material to combat moisture absorption and has very low loss properties. A cadmium plated saddle combines the functions of chassis fixing and retention of the screening can. To securely lock the can on the saddle, a slight twist produces a wedge action and eliminates all earthing noise and tendency to "rock". Brayhead have also developed and are developing further types of valveholders. Two types of screening can are available in the three standard sizes and can provide maximum heat dissipation with the close fitting can BHS/W/TV 53 ($1\frac{7}{8}$"), 54 ($2\frac{1}{8}$"), and 55 ($2\frac{5}{8}$"). Also low capacity with type BHS/W/TV 56 ($1\frac{7}{8}$"), 57 ($2\frac{1}{8}$") and 58 ($2\frac{5}{8}$").
Both types can be supplied in plain or matt black finish aluminium. For full information write or phone :—




# BRAYHEAD (ASCOT) LTD.

FULL VIEW WORKS · KENNEL RIDE · ASCOT · BERKS
*Telephone:* Winkfield Row 427 8 9 *Telegrams:* Brayhead, Ascot



# Plessey Precision Wound Components

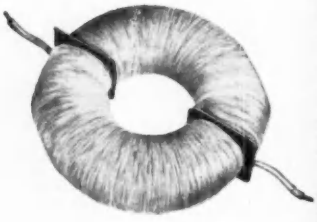
Plessey produce quality wound components for the communications and industrial electronics industries.

Specialist staff and manufacturing units are engaged in the design, precision production and testing of services type approved components, including for instance, oil-filled hermetically sealed 'C' core transformers and chokes.

Information and design data on typical ranges of Plessey Precision Components are available to designers and engineers in publication No. 920—which also includes details of:—

Hermetically Sealed Transformers and Chokes to American Military Specification MIL-T-27A as well as to R.C.S. 214 issue 2, Humidity Class H1. I.F. Transformers. Discriminator Coils. Miniature R.F. Encapsulated Coils. Filter Assemblies. Magnetic Reactors.

Open type 'C' Core transformer impregnated in solventless varnish to Inter-Service Specifications.



Toroidal Coils manufactured by Plessey include windings from ¼ in. internal finished diameter to 5 in. outside diameter wire sizes ranging from 48 s.w.g. to 21 s.w.g.

Plessey provide a complete design and winding service for ferro ceramic cored chokes and transformers.

**COMPONENTS GROUP · COILWINDING DIVISION · THE PLESSEY COMPANY LIMITED · ILFORD · ESSEX**

*Overseas Sales Organisation:* Plessey International Limited · Ilford · Essex · England · Telephone: Ilford 3040

CC1

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Somewhere, you may feel, somebody has this stock, . . . and you're right. It is here, in the Delanco organization waiting for you, because it is our business to see that it is here. It is our job to anticipate trends in demand and calculate with a fair degree of certainty what will be the current type of material on "Rush order".

As an example of our service our bonded store contains very considerable stocks of laminated bakelite sheet, meeting:—

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A very wide range of such materials, tested and released with the appropriate certification, are available with IMMEDIATE DELIVERY.

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# 1-amp junction diode with fractional μsec hole storage

## Outstanding performance in TWO functional groups

**In digital computers, square loop ferrite circuits and ring modulators**

The low hole storage and high current of this new junction diode particularly recommend it for this group of applications. The peak forward current is 1 amp at less than 1 volt drop, and its hole storage specification approaches that of a good point contact diode.

The OA10 can be very successfully employed as a coupling element in junction transistor circuits, particularly for computing applications. In addition its high current characteristics suit it for ferrite magnetic memory circuits in computing and shifting registers.

Applied as a ring modulation diode, the sharp forward discontinuity and the stability of that characteristic are outstanding.

| | | At 25°C amb. temp. | At 60°C amb. temp. |
|---|---|---|---|
| Max. reverse voltage, d.c. or peak | (V) | 30 | 30 |
| Max. forward current : | | | |
| Peak (5μsec max.) | (A) | 1 | 1 |
| Average (50msec averaging time) | (mA) | 100 | 100 |
| **Average Characteristics** | | | |
| Forward voltage (at 0.3mA) | (V) | 0.2 | 0.13 |
| ,, ,, (at 100mA) | (V) | 0.5 | 0.44 |
| Reverse leakage current (at −20V) | (μA) | 1.5 | 10 |
| Hole storage recovery time* | (μsec) | 0.35 | 0.35 |
| Capacitance (at −10V) | (pF) | 4.0 | 4.0 |

* For test conditions see published data

**In transistor power supplies**

The small size and low forward losses of the OA10 fit it for use as a general purpose mains rectifier for transistor power supplies. A single diode in a half-wave rectifier circuit will deliver up to 100mA d.c. at 6 volts. A bridge circuit will deliver up to 200mA at 12 volts.

In addition, the OA10 can be used as a non-linear temperature coefficient compensating device in germanium transistor circuits. It also finds application as a voltage stabiliser in its forward current direction where the voltage drop across it (about 0.4 volt) is relatively independent of current.

✳ *Full data on the OA10 and other diodes and Transistors in the Mullard range are available from the address below*

**Mullard**

COMMUNICATIONS AND INDUSTRIAL VALVE DEPARTMENT

Mullard

Mullard Limited,
Mullard House,
Torrington Place,
London, W.C.1

MVT 326

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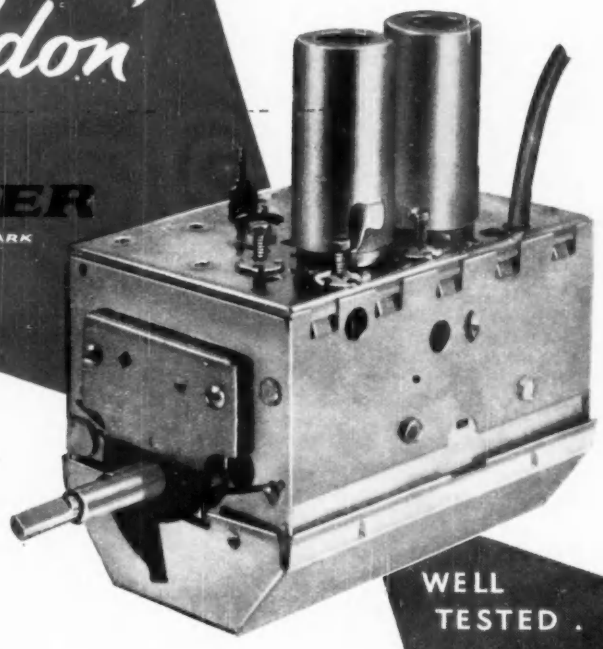
*with*

THE *'Cyldon'*
TURRET
TELETUNER
TRADE MARK



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WELL TRUSTED

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**easy alignment**

**and subsequent**

**Dealer maintenance**

● ***Full technical details and specifications gladly sent on application.***

Cyldon products have an enviable reputation for long life and reliability. They save time in assembling and testing, and after-service work is reduced to a minimum.

We will be pleased to help you with your radio and electronic problems. Our comprehensive resources and specialised experience are at your disposal.

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**AND SONS LTD.** POOLE DORSET

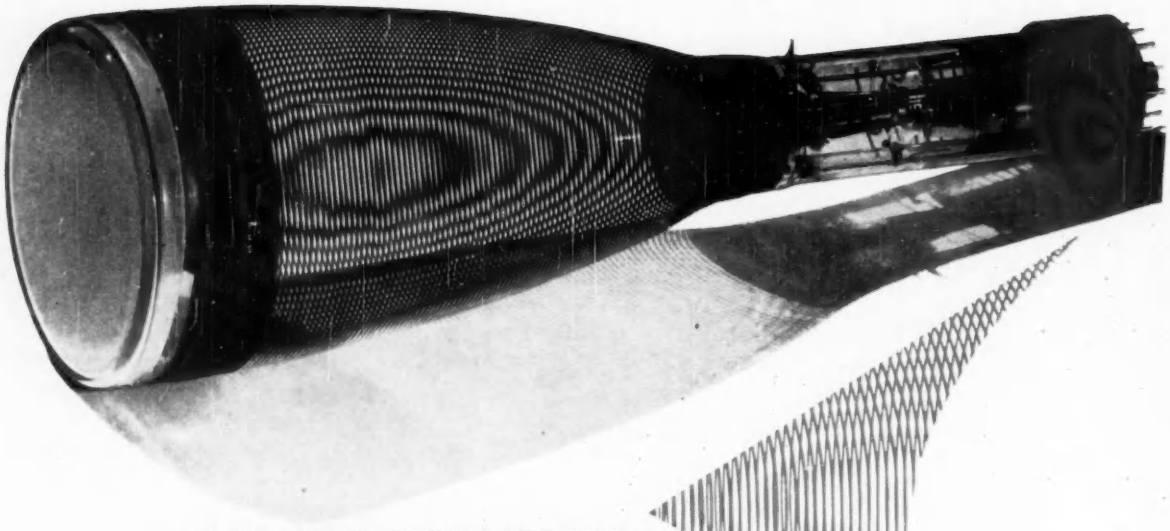
*Contractors to Ministry of Supply, Post Office, and other H.M. Government Depts.*

***Address for enquiries and sales correspondence :—***

**London Sales & Technical Liaison Office, 3 Palace Mansions, Palace Gardens, Enfield, Middlesex.**

*Telephone : Enfield 8571-3* *Telegrams : "Capacity-Enfield"*

# A NEW 'HIGH' IN C.R.T. SENSITIVITY



## 20th CENTURY'S TYPE S5AG

20th Century introduce the first of a new series of precision tubes employing helical P.D.A. systems. The tubes make possible a real advance in oscillographic techniques. The S5AG, available for early delivery, is designed to give the highest deflection sensitivity and minimum scan distortion together with small spot size.

*Screens:*
*The 'G' screen is a medium persistence green phosphor. Other types can be supplied on request.*

| CHARACTERISTICS | | |
|---|---|---|
| Type | | S5AG |
| Heater Volts | | 6.3 |
| $A_3$ typical | | 2 kV |
| $A_4$ typical | | 8 kV |
| Sensitivities at | X | 30 V/cm |
| $VA_4$ 10 kV $VA_3$ 2 kV | Y | 8 V/cm |
| Useful screen area | | 11x5 cm |
| Base | | B14A |

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CHWR9

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Now Simplex can quickly flameproof many of your products. Two special flameproof enclosures have been designed as standard for various controls and instruments. Both are ready Buxton certified for a number of applications, and it is probable that with only a short delay an extended certificate may be obtained to cover particular requirements.

These neat modern enclosures (one large, one small) may be variously joined to suit your individual needs. Send for particulars

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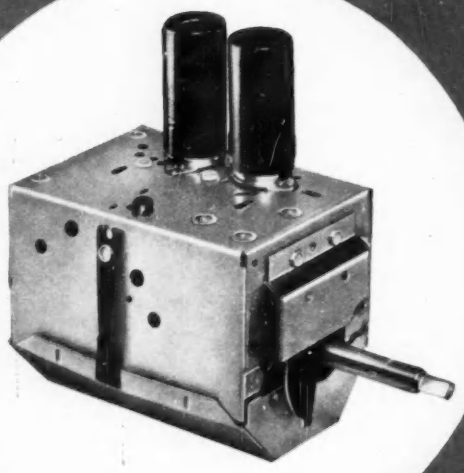

## ...with the TURRET TELEVISION TUNER!

This is the tuner which has become an overnight success with large and small manufacturers the world over. And no wonder! It can be produced to suit the *exact* requirements of *any* circuit . . . it is completely interchangeable with all other makes of tuners . . . streamlined to offer an unparalleled degree of efficiency in every set . . . and still undergoing day by day improvement both in mechanical and circuit layout. Yes, all these advantages—and still no increase in cost! If you haven't yet examined the full technical specification, write for information today. But first take a look at these outstanding features.

### SPECIAL FEATURES

*All coils have screwdriver adjustment, using either radial or axial coil formers.*
*Low loss mouldings.*
*Accurately controlled spring tensions for long life and ease of use.*
*Special Band Pass facilities available on all channels.*
*Increased fine tuner range.*
*Complete interchangeability of fixing holes and mouldings with current practice.*
*Black valve cans for better heat dissipation.*
*Increased gain, lower noise factor.*
*Negligible drift, reduced oscillator radiation.*
*Easy interchangeability of coils.*
*Ease of adjustment in the field to compensate for varying aerial conditions.*

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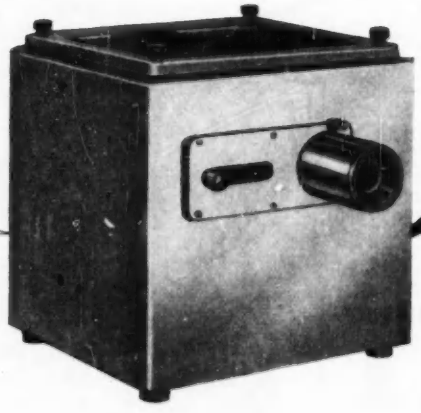
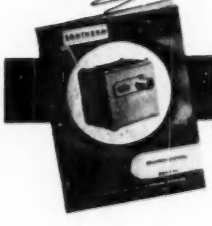
# Universal Oscillograph Recording Camera

For use with any standard oscilloscope. Type M731 for 35 or 70 mm. film or paper. Stills, continuous-feed to 100 inch/sec., and drum to 1200 inch/sec. F = 3-inch f/1.9 lens.



*A copy of our Type 731 Camera Brochure will be gladly sent, on request.*



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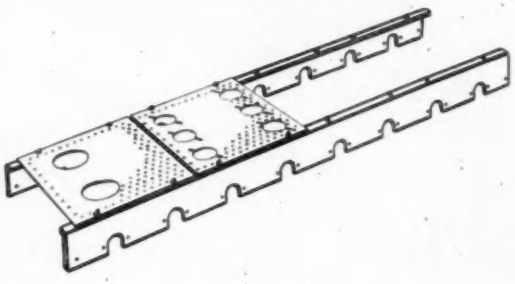
# ASK YOURSELF!

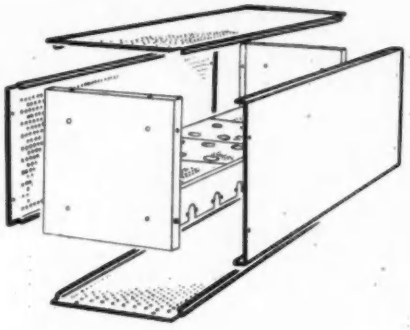
LEKTROKIT



***HOW LONG***
does it take?

***HOW MUCH***
does it cost?

to produce an experimental chassis

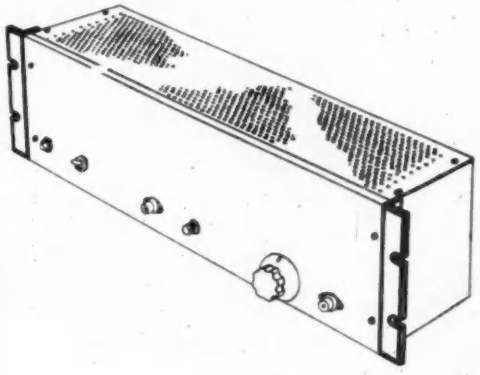


If you don't already know, please spare a while to find out.

Then, when you are horrified by the answers, spare a little more time

to

***investigate***



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# New value in valveholders

A *ceramic* valveholder with its many inherent advantages, costing no more than the ordinary moulded varieties — this is the latest news from Plessey at Towcester. This superior product employs high-grade, low-loss ceramic body material and has a pin-to-pin capacity of *less than 0.5 pf*.
Design Engineers, manufacturers and others interested in this cost-cutting, performance-improving development, should request a copy of Plessey Data Sheet No. 6062 which contains comprehensive data.

## Parameters

Equivalent Resistance at 20 Mc. between 2 adjacent contacts:
Not less than 3 megohms

Insulation resistance:
Greater than 20 x $10^{12}$ ohms

Voltage Breakdown:
Greater than 3.5 Kv pin-to-pin and pin-to-earth

Contact Resistance:
Less than 4 milliohms

Contact Material:
Spring quality Brass — Silver Plated

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Putting two and two together and making five ! At least, that's how it appears when you consider the saving in time and cost by changing over to tapping screws.
Without doubt, the tapping screw does display a number of very definite advantages over the conventional machine screw. It obviates the use of nuts. With its self-locating point, it forms its own thread and eliminates a separate and expensive tapping operation.
It makes for easier assembly, is stronger, cheaper and faster. And when used in conjunction with the Phillips recessed head, designed for power driving without damage to either work or worker, it is obviously safer. Putting two and two together, the tapping screw simply ensures a better job.
Why not change over to tapping screws and prove it for yourself?

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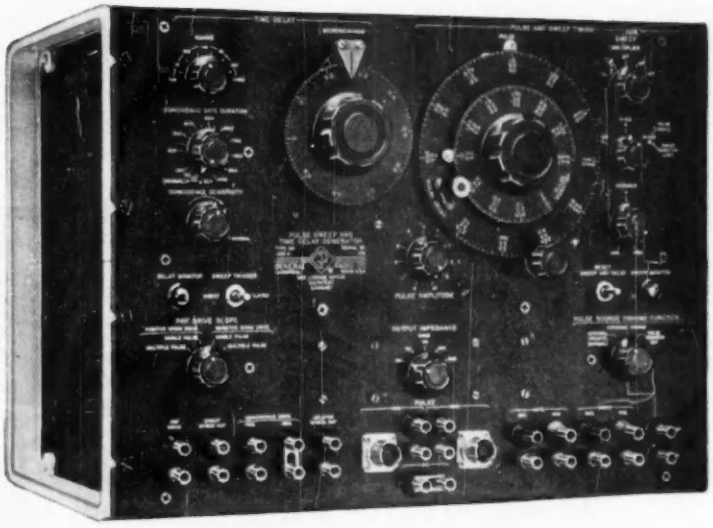
***An extremely versatile generator for time-domain measurements***



TRADE MARK

## 'GENERAL RADIO' TYPE 1391-A

# PULSE, SWEEP AND TIME-DELAY GENERATOR

The new Type 1391-A Pulse, Sweep and Time-Delay Generator performs, individually and in combination, all the functions described by its title and performs them all well; its excellent performance results from a minimum number of compromises in design. Its wide ranges and complete flexibility of circuit interconnection make it a highly satisfactory pulse generator for laboratories engaged in time-domain measurements and waveform synthesis.

The transition times of the output pulses are compatible with most present-day oscilloscopes. The internal sweep circuit makes it possible to deflect an inexpensive oscilloscope by direct connection to the deflecting plates, to monitor the output pulse.

Among its many applications are measurement and testing in the fields of:

| | |
|---|---|
| Echo ranging | Computers |
| Radio navigation | Telemetering |
| Television | Physiological research |

**DESCRIPTION** The Pulse, Sweep and Time-Delay Generator consists of the following major circuit groups: (1) input synchronizing circuits, (2) delay and coincidence circuits, (3) sweep circuits, and (4) pulse-timing and pulse-forming circuits.

## 3 INSTRUMENTS IN 1

**PULSE GENERATOR SWEEP GENERATOR TIME-DELAY GENERATOR**

This is truly a *complete* Time-Domain Measuring Instrument, giving the best performance obtainable with ultra-modern techniques plus the finest obtainable materials and components, backed by over forty years manufacturing experience. A very well thought-out design, developed over several years, provides the pulse specialist with the equipment he has long been seeking.

**SUPERIOR PULSE CHARACTERISTICS:**
Excellent Rise and Decay Times: 0·025 ± 0·01 μsec. No Duty-Ratio or Frequency Restrictions on the Pulse.

**HIGH BASIC TIMING ACCURACY:**
Timing Scales are Linearly Calibrated, and accurate to 1%.

**WIDE RANGES OF:**

PULSE DURATION: 0·05 μsec — 1·1 sec.
PULSE REPETITION RATE: 0 - 250 kc.
TIME DELAY: 1 μsec — 1·1 sec.
DELAY REPETITION RATE: 0 - 400 kc.
OUTPUT IMPEDANCE: 0 - 600 ohms.

This is a large instrument, and it is supplied complete with its necessary power supply (not illustrated), arranged at choice for bench or rack operation. The Generator proper has thirty-six vacuum tubes. Considering its flexibility and completeness the price is reasonable —£1,047 net delivered (U.K. only). For complete data see the 13-Page article in "GENERAL RADIO EXPERIMENTER" for May 1956, (Vol. 30, No. 12) or request the latest "G.R." Catalogue '0' Send your written application to our nearest address, please.

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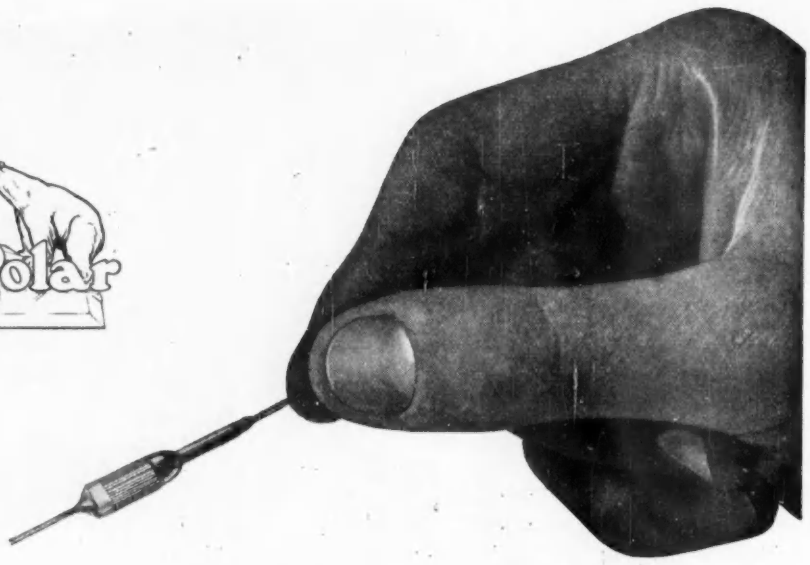

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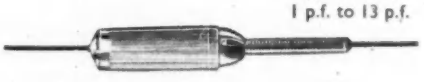
For radio, T.V., telecommunication work, and, in fact, all applications where small size, low loss and maximum stability are essential this range of POLAR miniature condensers meets most requirements.
The base of vane type condensers is of low loss ceramic. Vane assemblies can be silver plated brass, soldered throughout, or alternatively, vanes may be aluminium securely fixed to brass shaft and stem.
Both rotor contact and stator tag are silver plated. Insulation resistance is better than 1,000 meghoms at 500 volts D.C. Power factor is not greater than .001 at 1 Mc/s.
Two types of tubular trimmer are available. S50 using P.T.F.E. as a dielectric and S55, for panel mounting, using glass bonded mica.
Type S50 is made in two sizes having capacities from 0.7pF—4.0pFs. and 1 pF—13pFs. respectively.
Type S55 is made in one size only, with a capacity from 1pF to 10pFs. Power factor is not greater than .001 at 1 Mc/s and the insulation resistance is not less than 1,000 megohms at 500 volts D.C.

**Type C.3201**
4.5 p.f. & 10 p.f.

**Type S.5001/2**
.7 p.f to 4 p.f.



**Type S.5011/3**
1 p.f. to 13 p.f.

**Type S.5511**
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**Type C.3111**
19.5 p.f. & 33 p.f.

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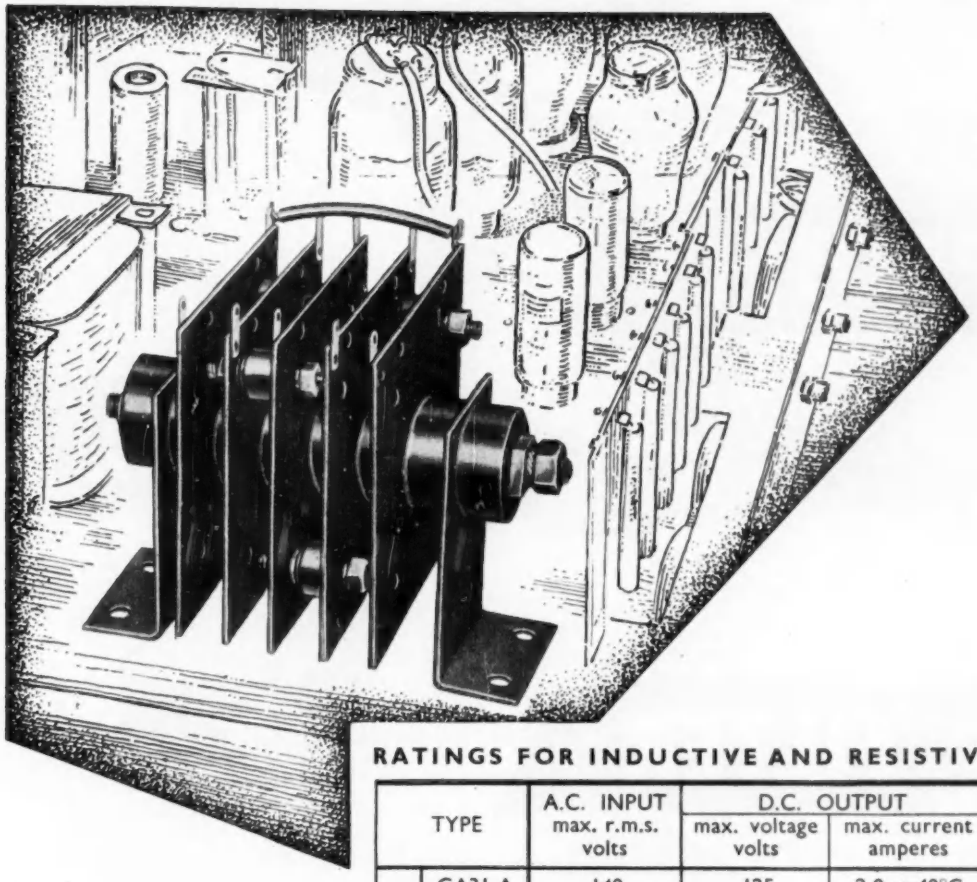
# GERMANIUM JUNCTION RECTIFIERS
## — finned bridge units



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| | TYPE | A.C. INPUT max. r.m.s. volts | D.C. OUTPUT max. voltage volts | D.C. OUTPUT max. current amperes | OVERALL LENGTH inches |
|---|---|---|---|---|---|
| SINGLE-PHASE | GA31-A | 140 | 125 | 2·0 at 40°C | 3½ |
| | GA41-A | 53 | 47 | 2·0 at 60°C | 3½ |
| | GA51-A | 210 | 187 | 2·0 at 40°C | 3½ |
| | GA61-A | 106 | 94 | 2·0 at 60°C | 3½ |
| | GA52-A | 340 | 303 | 2·0 at 40°C | 5 |
| | GA62-A | 170 | 151 | 2·0 at 60°C | 5 |
| | GA53-A | 510 | 455 | 2·0 at 40°C | 6½ |
| | GA63-A | 254 | 227 | 2·0 at 60°C | 6½ |
| THREE-PHASE | GB31-A | 140 | 188 | 3·0 at 35°C | 4⅝ |
| | GB41-A | 53 | 71 | 3·0 at 55°C | 4⅝ |
| | GB51-A | 210 | 283 | 3·0 at 35°C | 4⅝ |
| | GB61-A | 106 | 143 | 3·0 at 55°C | 4⅝ |
| | GB52-A | 340 | 458 | 3·0 at 35°C | 6¾ |
| | GB62-A | 170 | 229 | 3·0 at 55°C | 6¾ |

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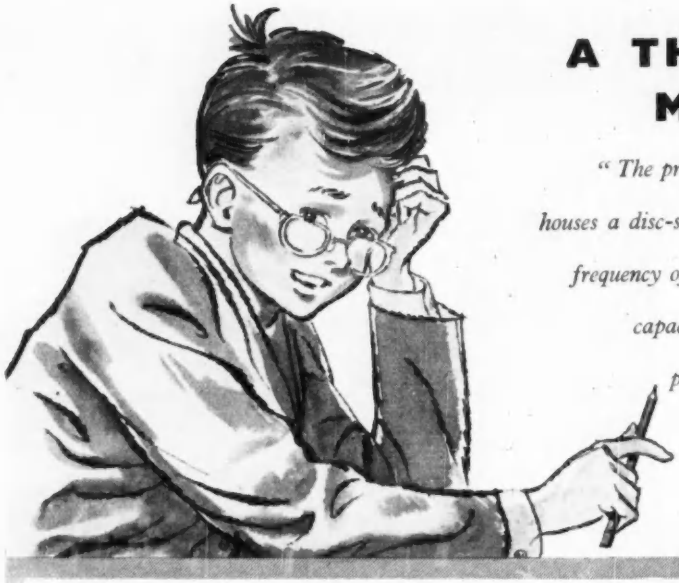

# A THOUSAND MEGACYCLES!

*" The probe unit used for a.c. measurements houses a disc-seal diode rectifier whose resonant frequency of 3,000 Mc/s, low inter-electrode capacitance and short transit time make possible a frequency range extending to no less than 1,000 Mc/s."*

WHERE *does* our young friend get all his information about Marconi instruments? He certainly knows all about our new TF 1041A. He knows that, in addition to its unequalled performance in a.c. measurements, it measures balanced or unbalanced d.c. voltages and a wide range of resistance values. He knows that it has a large mirror-scale meter for fast, precise reading. He knows that there are three optional accessories for extending the a.c. and d.c. ranges and for making measurements on coaxial lines. In short, there's nothing about the TF 1041A that he *doesn't* know.

Infuriating, isn't he? Still, there's no reason why you shouldn't be just as well-informed. All the facts about this Marconi instrument are given in our leaflet J113. If you'd like a copy, you have only to ask. That's the way to get information about *any* Marconi instrument. Just ask.

**THE *NEW* MARCONI**
**VACUUM TUBE VOLTMETER Type TF 1041A**

*A.C. Measurement:* Range: 0·05 to 300 volts, or to 2 kV using multiplier. Frequency Response: ± 0·2 dB from 50 c/s to 450 Mc/s, −1 dB at 20 c/s, + 2 dB at 1000 Mc/s. Input Impedance: 5 MΩ at 1 kc/s with 1·5 μμF in shunt.

*D.C. Measurement:* Range: 0·02 to 1000 volts, or to 30 kV using multiplier. Input Resistance: 40 MΩ balanced.

*Resistance Measurement* Range: 0·2 ohm to 500 MΩ.

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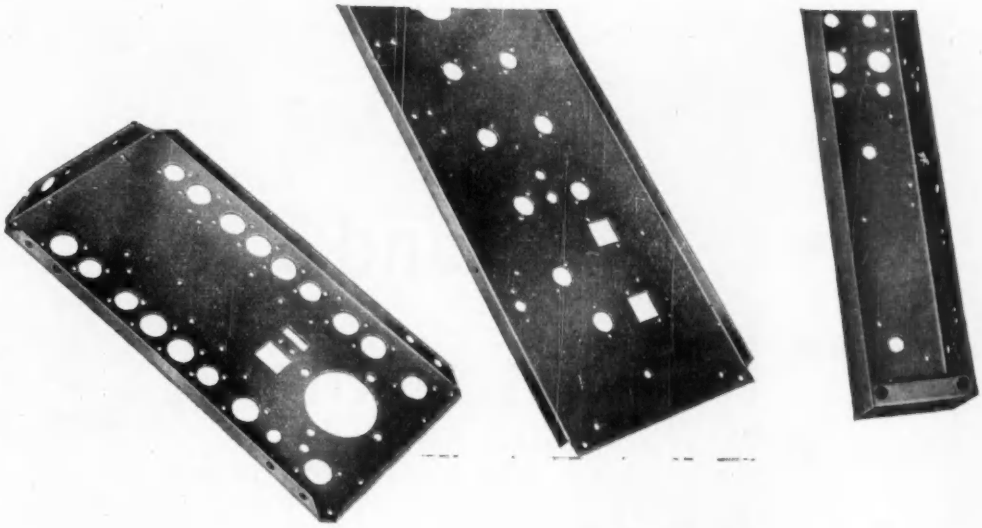

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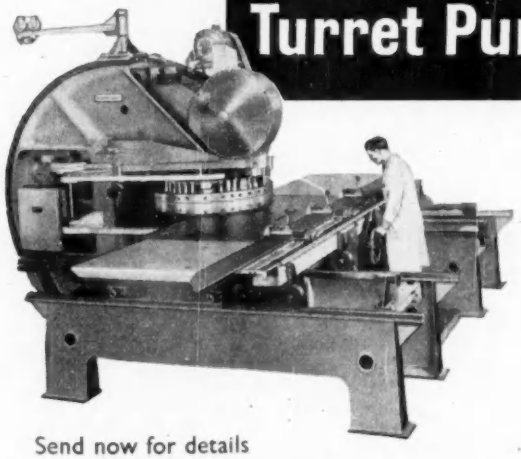
## British-built WIEDEMANN Turret Punch Presses



Send now for details of the **WIEDEMANN** method— or better still—time studies of your own piercing jobs

Start saving now by the Wiedemann method. From 12 to 32 interchangeable punches and dies can be readily mounted in the turret and the required punch instantly indexed to the working position. Punches of any shape or size can be supplied. There's a complete range of machines —hand as well as power—to cover all piercing requirements up to 160,000 lb. Hole location by simple 'pip' method, pantograph table, or direct measurement from gauge table.

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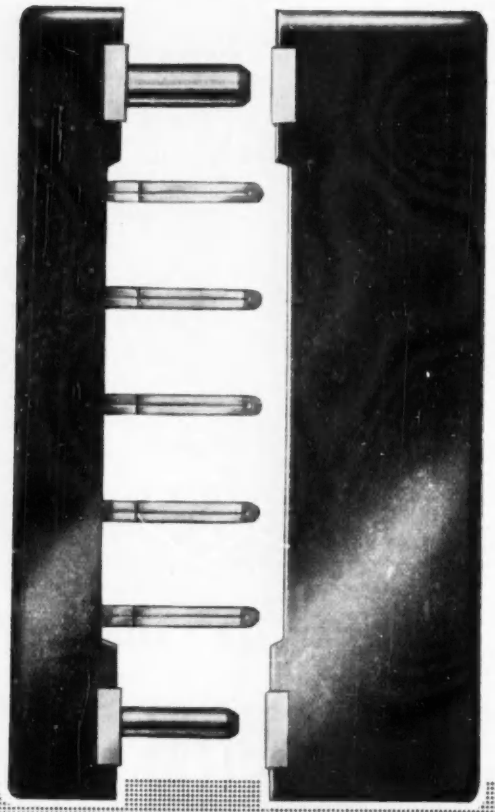

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Well proven plug and socket contacts are used and exceptional freedom in dimensional tolerances of fixings etc. has been provided for.

5 and 7 Way versions are available and the Connectors can either be mounted direct to the panel where clearance is provided for contacts or mounted on stand-off pillars.

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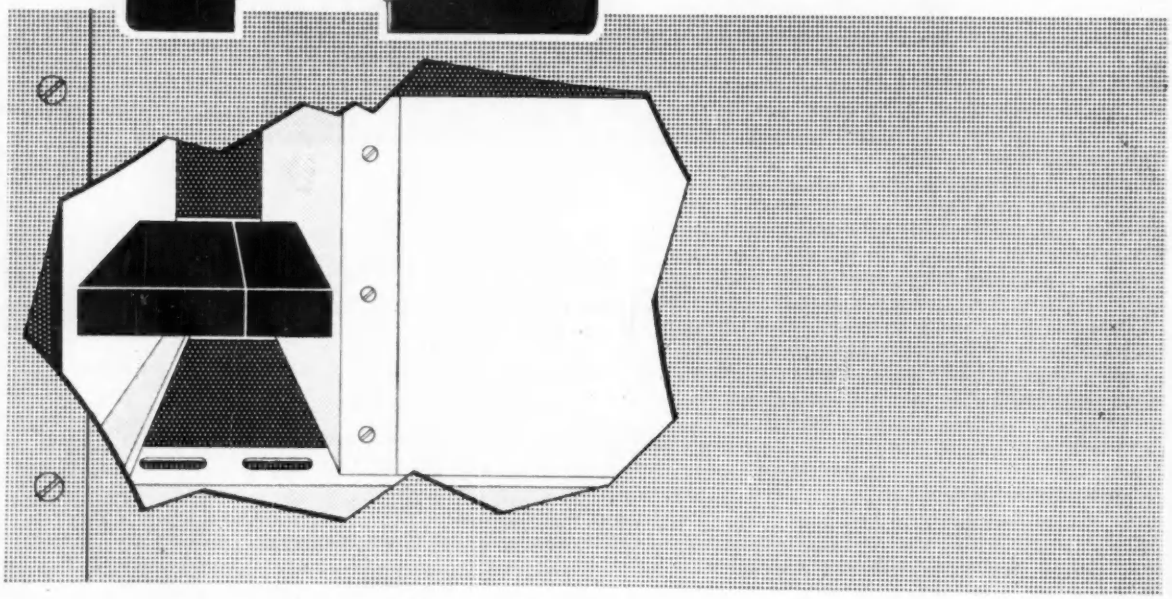

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# NEW...
# COMPACT...

## series 320 relay

This relay is of compact design and extremely small for the duty it performs, the contact arrangement is three pole double throw and connections to contact and coil are conveniently brought out at one end of the relay.

Contacts and terminations are housed in a high grade Bakelite moulding and the design of the moulding gives increased creepage path and excellent insulation. Guards are fitted to avoid flashover between contacts.

*Maximum Working Voltage:* 440 volts A.C. 50 cycles.
*V.A. Rating:* 5 V.A.
Contacts rated up to 10 amperes at 250 volts A.C. or 30 volts D.C.

*Series* 325 *Relay.* The only difference is that this is a D.C. Relay and the maximum working voltage is 250 volts D.C.
*Wattage:* 2 watts.
Contacts rated up to 10 amperes at 250 volts A.C. or 30 volts D.C.

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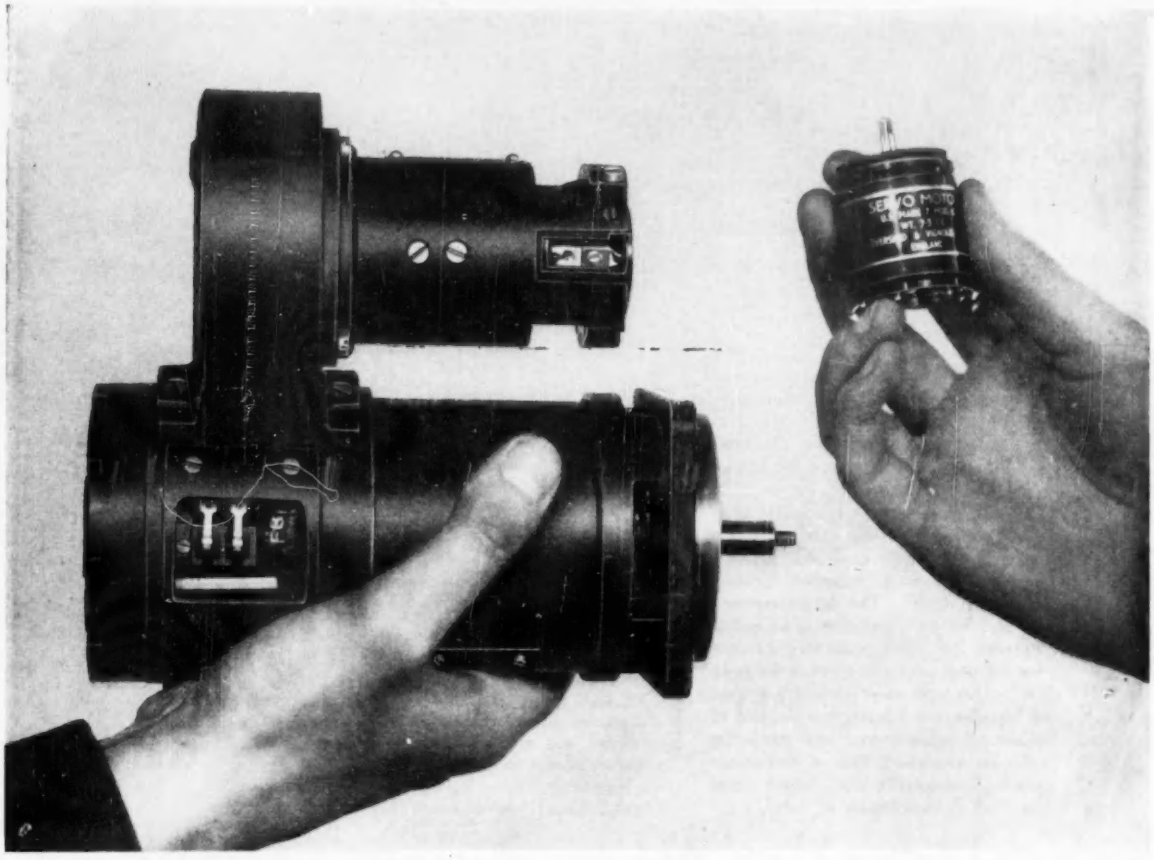

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# NEW...
# COMPACT...

## series 320 relay

This relay is of compact design and extremely small for the duty it performs, the contact arrangement is three pole double throw and connections to contact and coil are conveniently brought out at one end of the relay.
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*V.A. Rating:* 5 V.A.
Contacts rated up to 10 amperes at 250 volts A.C. or 30 volts D.C.

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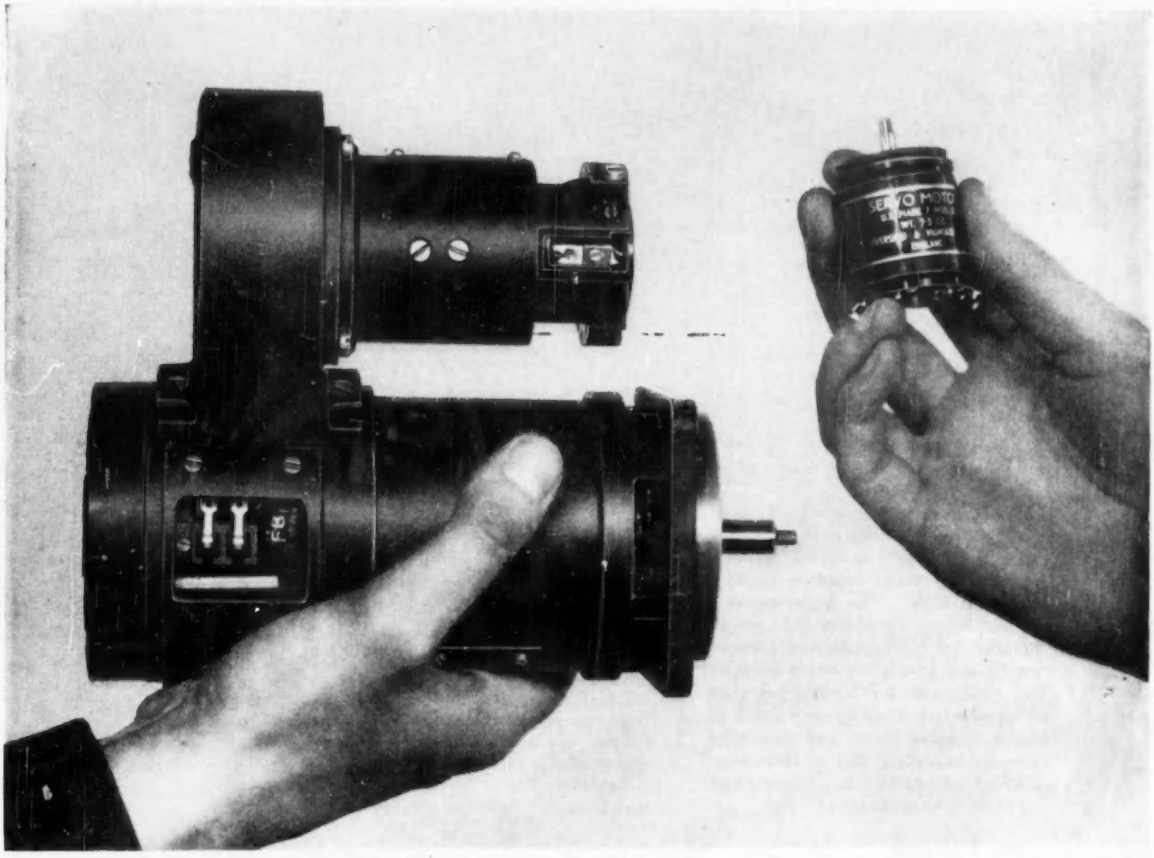

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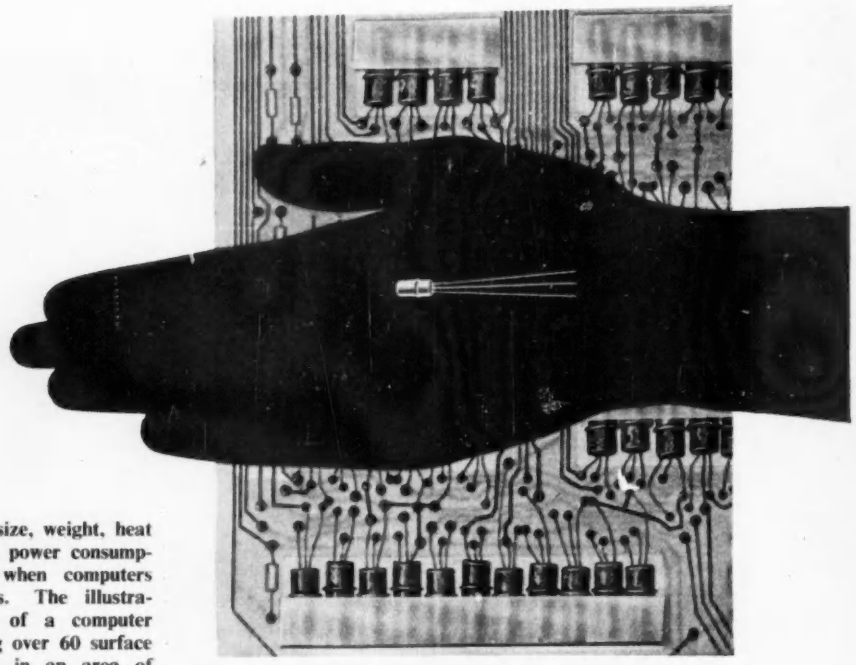

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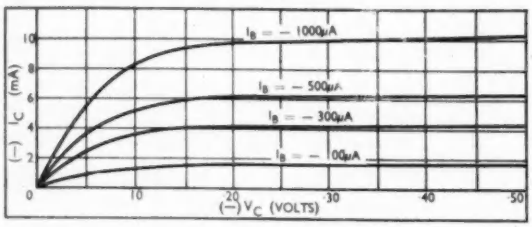


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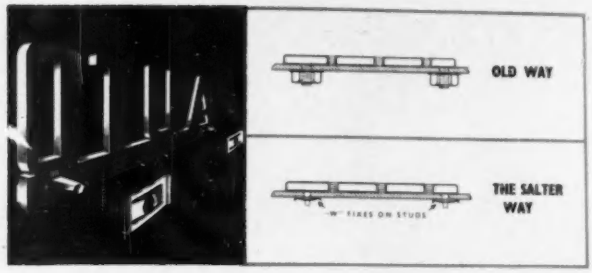


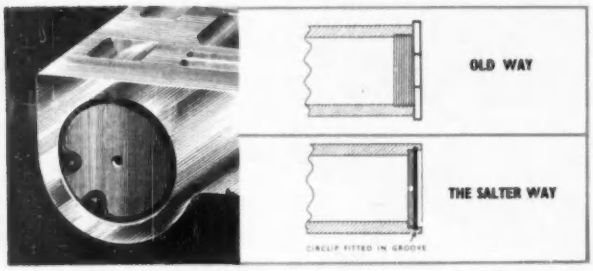


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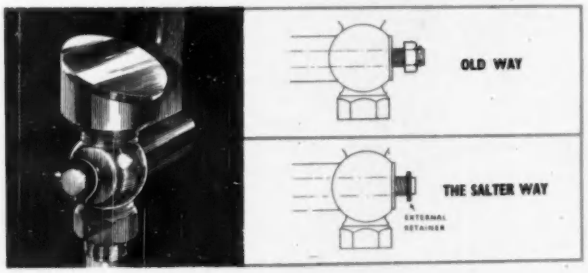


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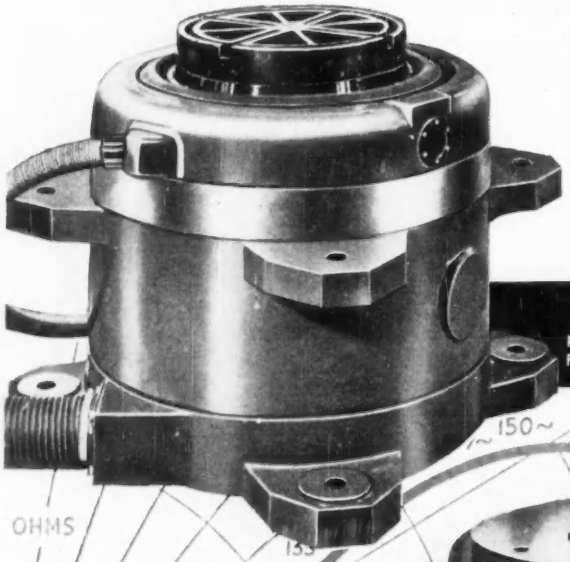

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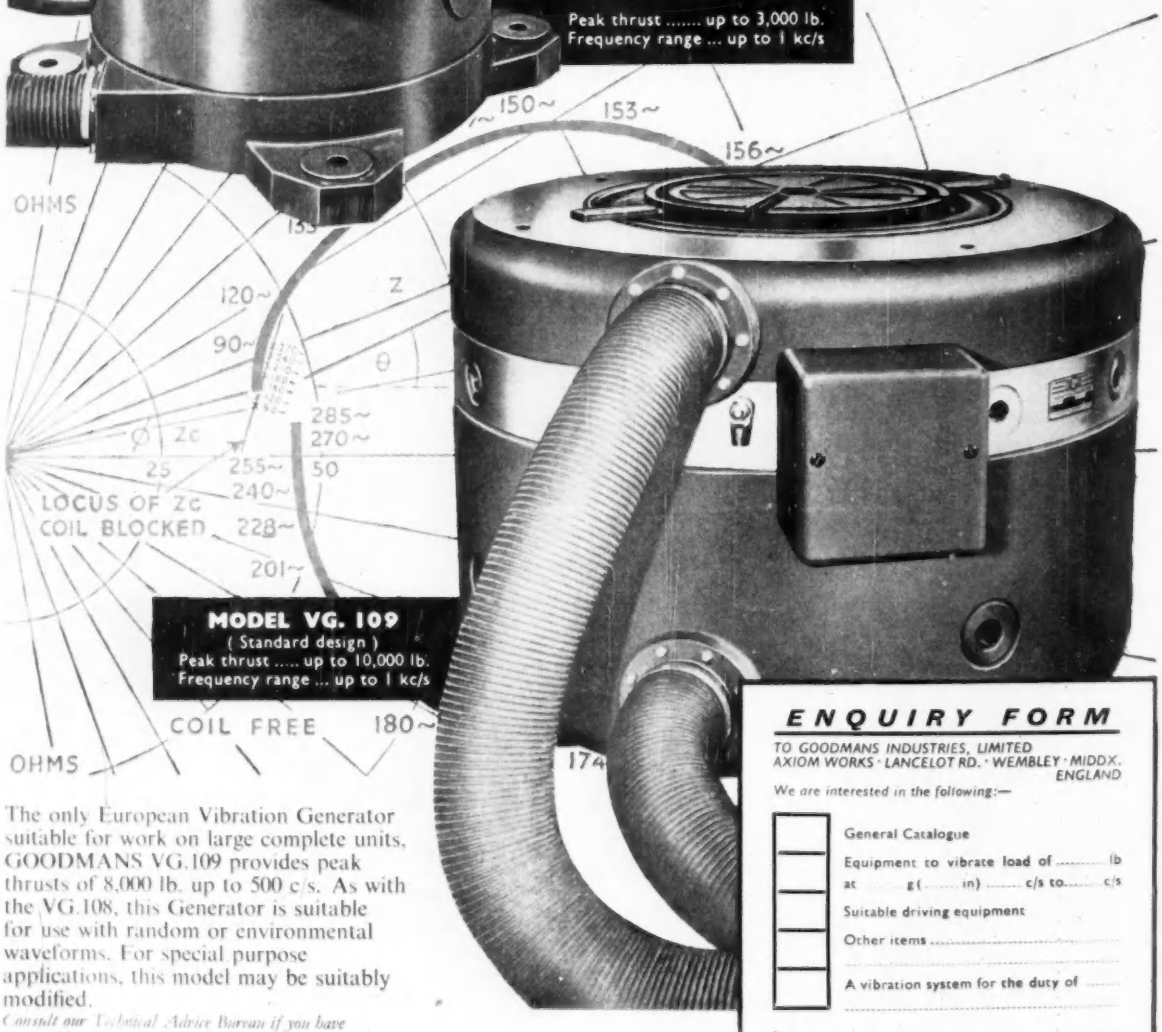
Frequency range ... up to 1 kc/s

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( Standard design )
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Frequency range ... up to 1 kc/s

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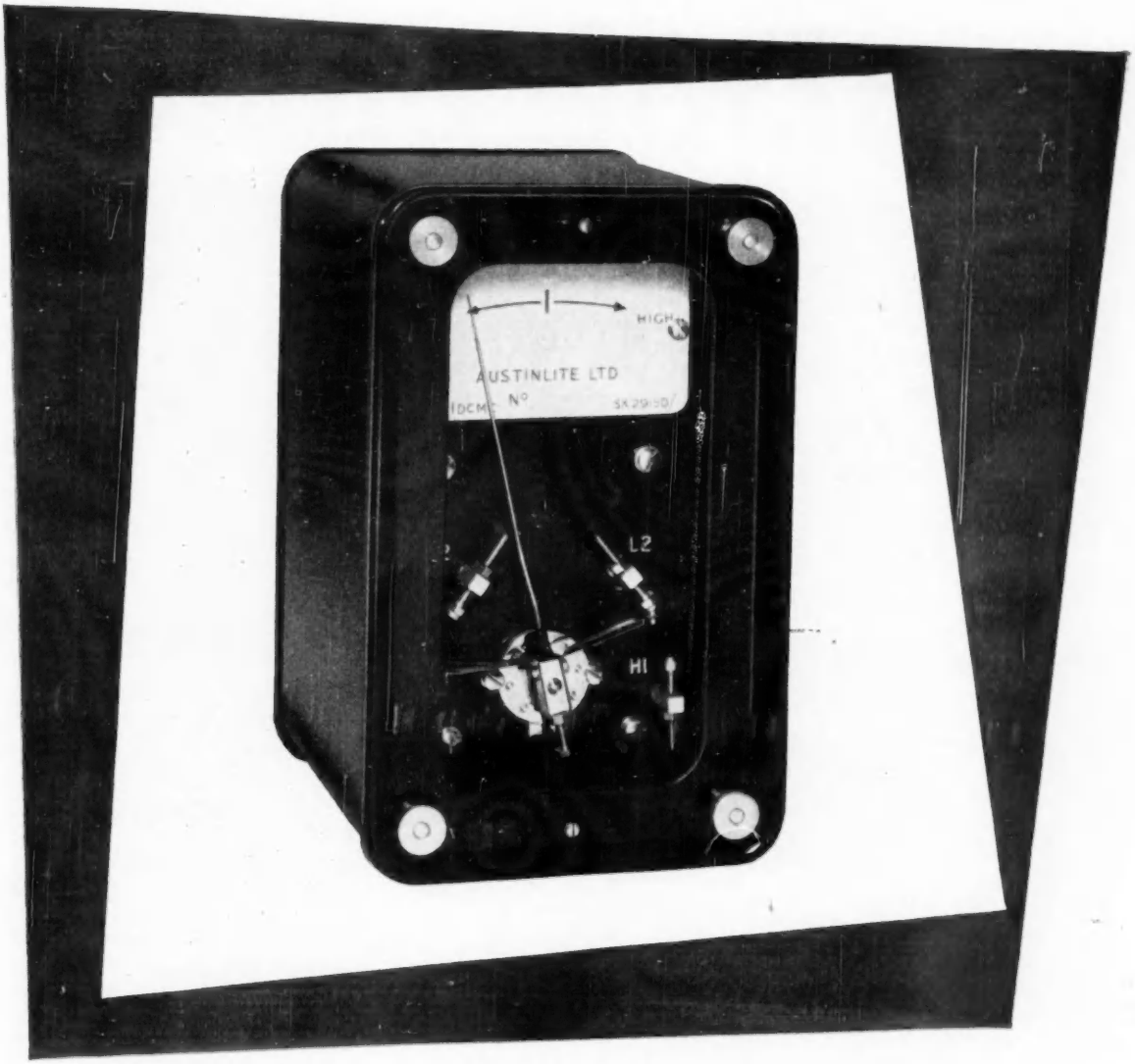


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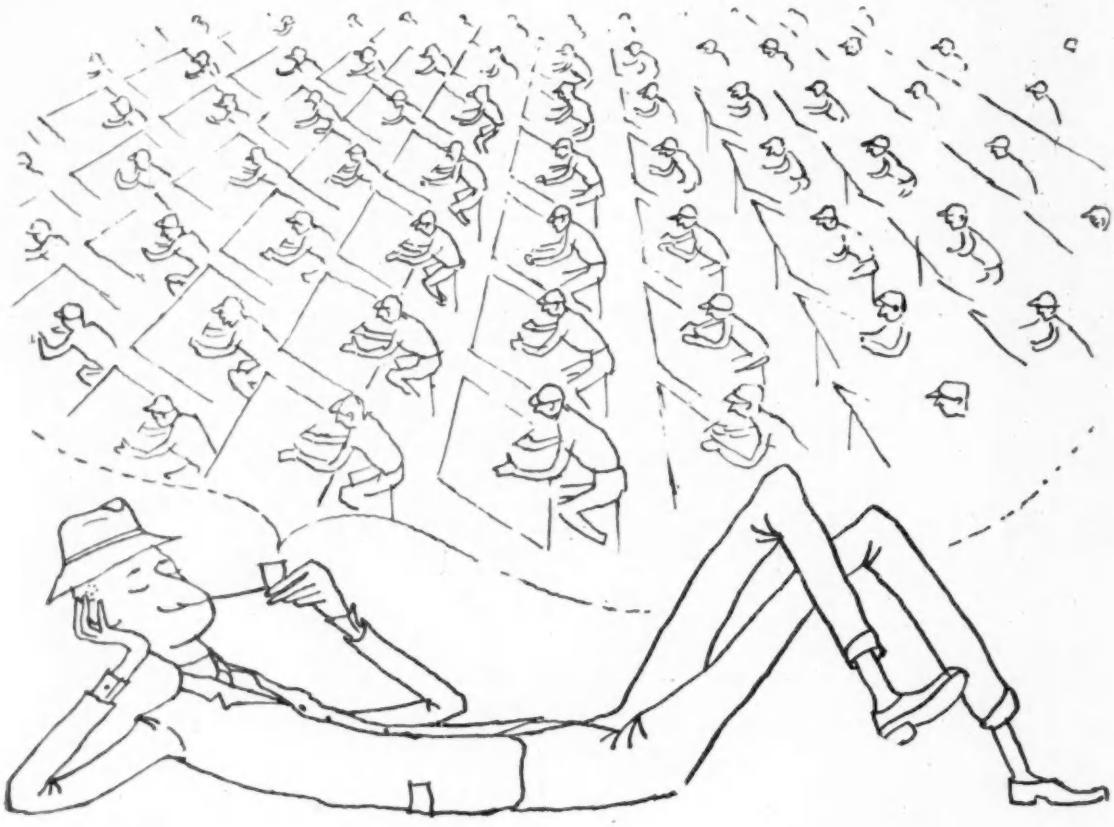

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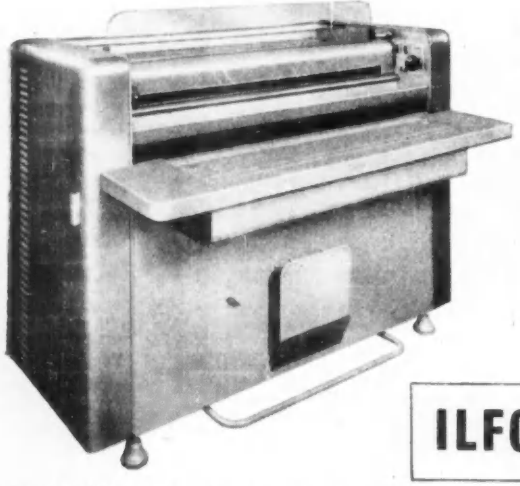

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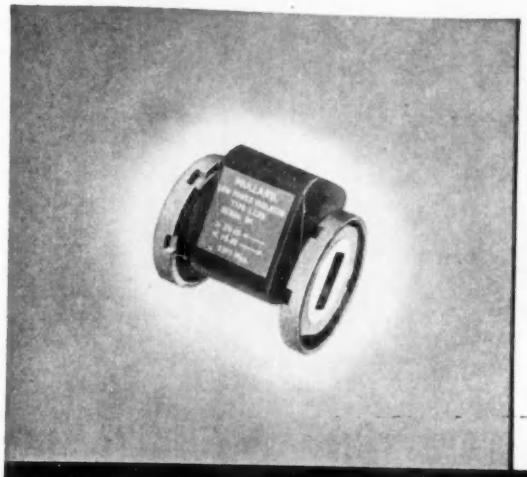
# X band isolators



## Low power isolator L250

The X-band isolator L250 is a non-reciprocal waveguide component having an insertion loss in the direction of propagation of less than 1.0dB and a reverse loss of greater than 20dB at the centre frequency. The bandwidth is such that over a range of 900 Mc/s centred on 9375 Mc/s the reverse loss is greater than 15dB while the insertion loss remains less than 1.0dB. The device depends for its action on the non-reciprocity exhibited by ferrite materials at microwave frequencies. This property is due to the phenomenon of gyromagnetic resonance. The device will find applications in the fields of radar, communications and microwave investigation in the laboratory.

## High power isolator L251

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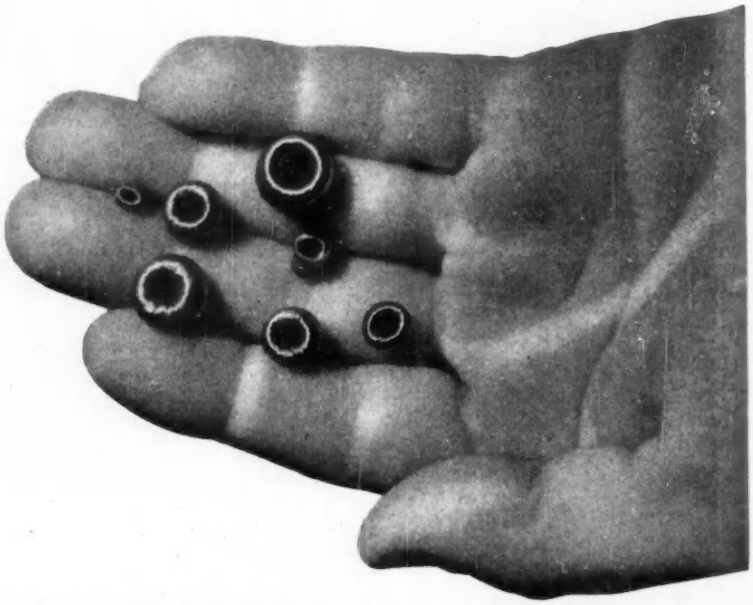

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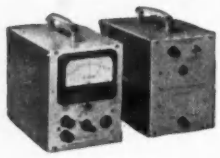

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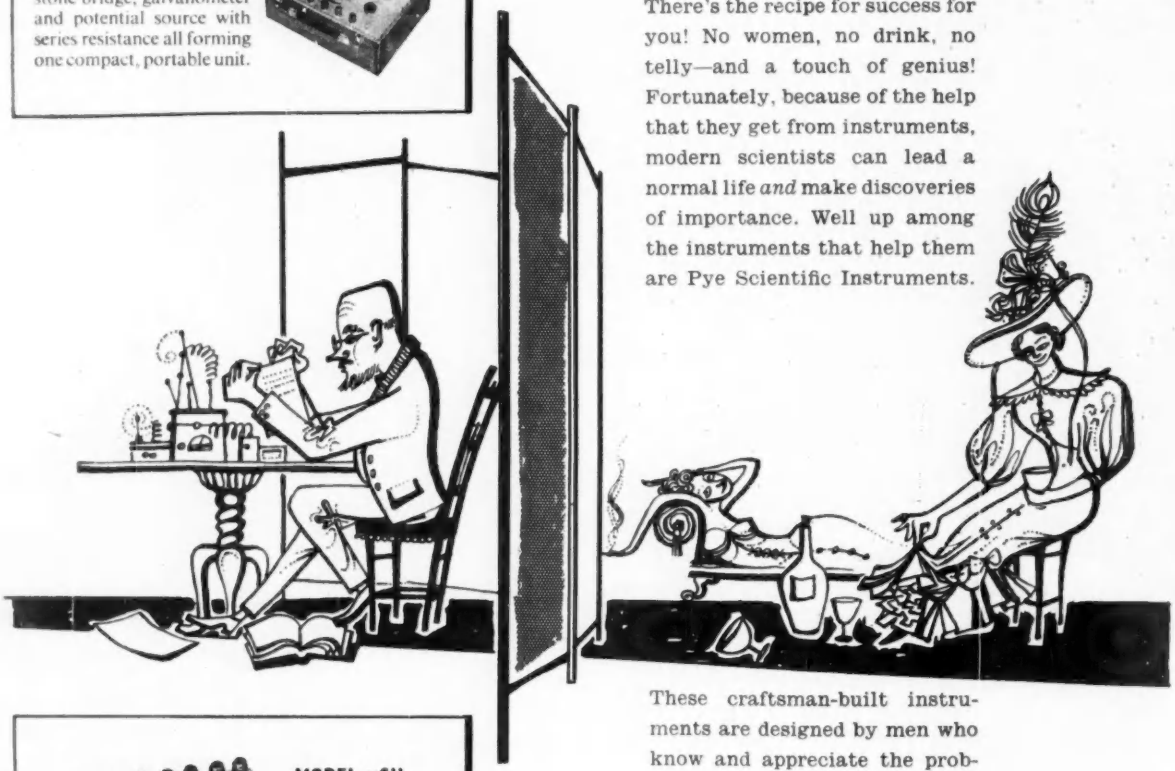

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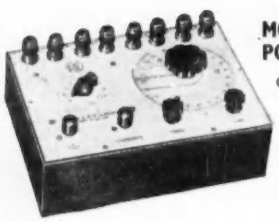

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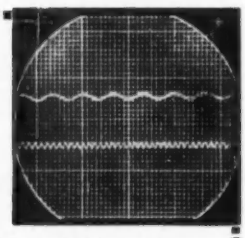

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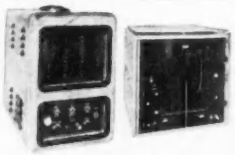

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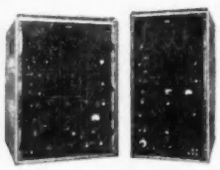

**SA.28 FREQUENCY METER:** 10 c/s to 30 Mc/s. Designed for swift and accurate measurement of frequencies by unskilled personnel. Also available in one unit with the RA.49 **Droitwich Receiver.**

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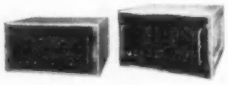

**SA.45 MICROSECOND CHRONOMETER**
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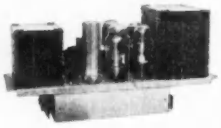

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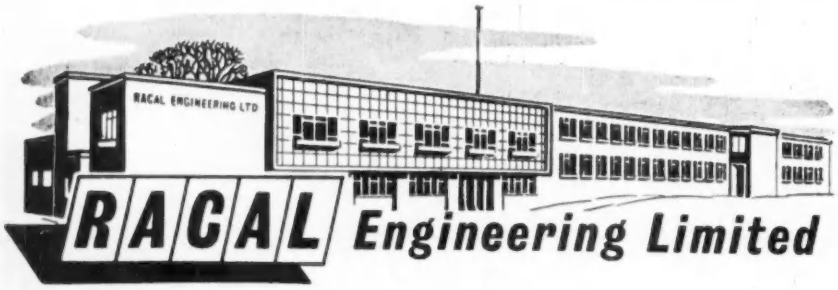


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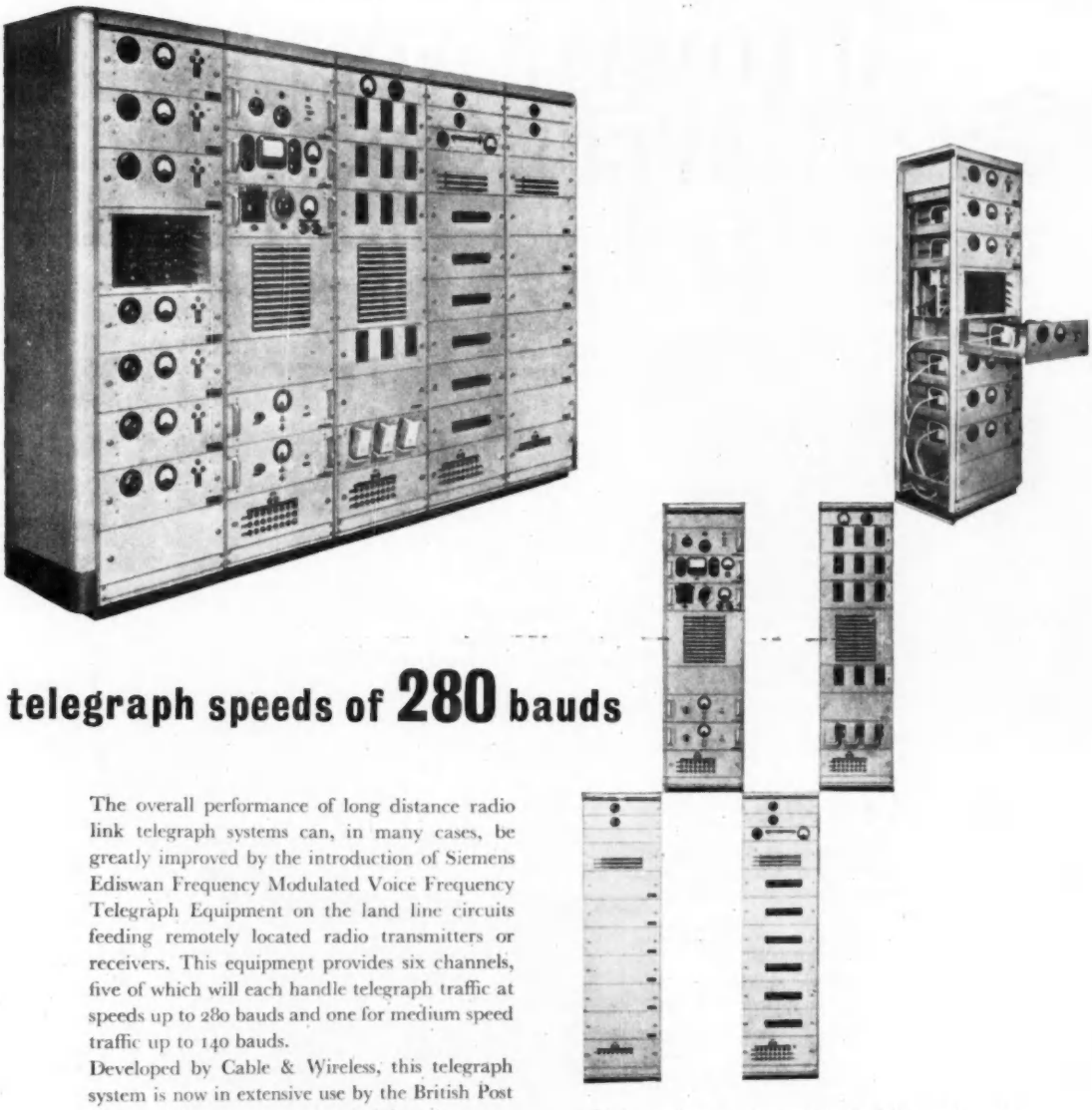

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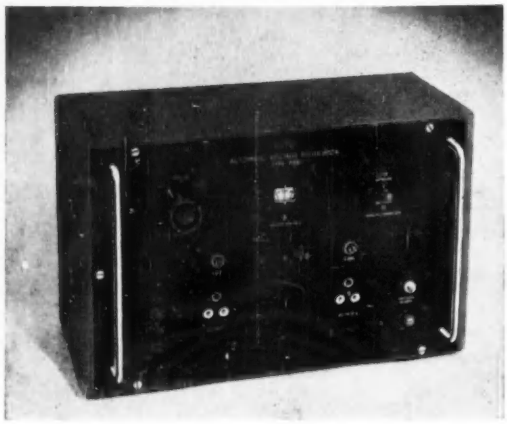

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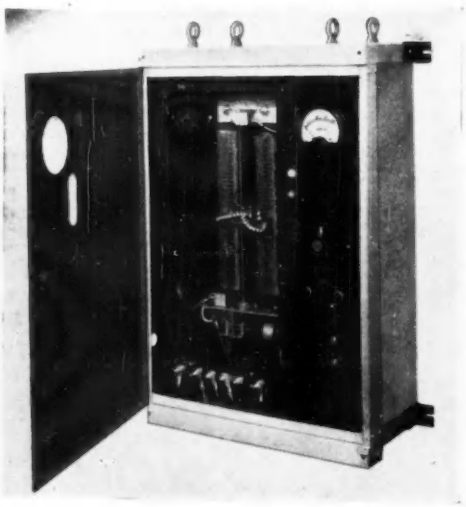

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Vol. 30
No. 359

JANUARY 1958

# Electronic Engineering

Managing Editor: H. G. FOSTER, *M.Sc., M.I.E.E.*

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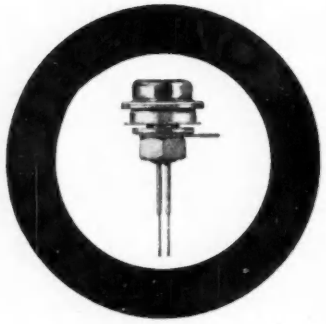

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**Characteristics** (measured at 25°C ambient)

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Current amplification

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at Ic = 300mA .....35

at Ic = 2A .....22

at Ic = 3A .....16

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| AMBIENT TEMP. (TO GIVE 75°C JUNCTION TEMP.) | DISSIPATION WITH INFINITE HEAT SINK, e.g. WATER COOLED | DISSIPATION WITH LARGE METAL PLATE 1°C PER W THERMAL RESISTANCE | DISSIPATION WITH 1 sq. ft. METAL PLATE 2°C PER W THERMAL RESISTANCE | DISSIPATION WITH SMALL METAL PLATE (4 in. x 7 in.) 5.5°C PER W THERMAL RESISTANCE |
|---|---|---|---|---|
| 25°C | 45W† | 24W | 16W | 7.6W |
| 35°C | 36W† | 19W | 13W | 6.1W |
| 45°C | 27W† | 14W | 9.7W | 4.6W |
| 55°C | 18W | 9.5W | 6.5W | 3.0W |

† *Continuous dissipation values in excess of 24W are at present prohibited by the voltage and current ratings given in the full data*


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ELECTRONIC ENGINEERING

VOL. 30 No. 359

JANUARY 1958

# *Commentary*

THE figures, so far as they are available, show that 1957 has been another year of considerable prosperity for this country's manufacturing industries, and the electronic industry has joined in this prosperity to the full. This is shown in the production and, particularly, export figures, which in most spheres of the industry are at record levels. For the first ten months of the year the total exports of all radio and electronic equipment were valued at £36·2M against £32·8M for the same period of the previous year, so that for the complete year this should give a total of some £43M against the record of £40M achieved in 1956. The growth of interest in British electronic equipment has also been evidenced by the large attendances at the various exhibitions held throughout the year, and here one may remark on the success of the first Instruments, Electronics and Automation Exhibition which provided the industry with an excellent opportunity to show some of the more serious sides of its activities.

From the scientific aspect it has, perhaps, been a year of consolidation and solid progress rather than of spectacular discovery or invention; though it must always be borne in mind that the full import of a discovery or invention is seldom realized until some considerable time after its inception.

In the manufacturing industries the use of electronic devices has continued to grow rapidly and in many industries the use of various forms of electronic equipment is completely accepted as a means for measuring and controlling both the quality and quantity of production. Progress has also been made in the electronic control of machine tools and during the year several new forms of control element have made their appearance. In the past the electronic control has usually been added to existing designs of machine tool but milling machines, etc. designed specifically for electronic control are now in production.

Although considerable research on new switching and memory elements is still proceeding the basic design of the digital and analogue computer is fairly well established and the main emphasis is now towards the useful and profitable application of these machines and their integration into complete systems. In the commercial world, payroll accounting is still the most profitable application for the digital machine and a number of the larger firms are now making use of them. As for example, the Ford Motor Company who are using LEO I for computing the payroll for their 19 000 employees. The G.P.O. has also ordered two National Elliot '405' computers to handle the payroll accounting for some 112 000 employees while similar installations are being made by several town and county councils. The scientific use of both analogue and digital machines has also continued to expand and installations have been made for such diverse applications as weather forecasting, biophysical research and wind tunnel data processing. The weakest part of a computer installation is, in general, the input and output which is usually slow compared with the speed of the machine itself. To overcome this and thus increase the range of application of the computer considerable work has been done; notable examples being the Solartron 'Electronic Reading Automaton' which will 'read' printed or typewritten characters at a speed of 120 characters/second, and the Powers-Samas 'Samstronic' tabulator which is capable of printing characters at a speed of 700 characters/second.

The entertainment side of the industry has also had a most successful year. Compared with 1956 the total sales of radio receivers has risen by about 20 per cent radio gramophone and audio equipment by 26 per cent and television receivers by 2 per cent. The sales of radio receivers has, no doubt, been stimulated by the introduction of f.m. broadcasting, while the small increase in the sales of television receivers is probably due to the fact that this is rapidly becoming a replacement only market. The ever-increasing popularity of recorded music is, however, rather more difficult to account for but is probably due, in part, to the very high standard of recording and reproduction that is now offered. One of the most notable events during the year has of course been the 21st birthday of the BBC television service; a service which now caters for 98 per cent of the country's population. With the virtual completion of their Band I programme the BBC is now actively pursuing the possibilities of colour with test transmissions in Band I and are also carrying out a series of tests in Band 5. On the manufacturing side the year has seen considerable progress in the introduction of transistors and printed circuits into domestic equipment; the latter may make for cheaper and more foolproof production but it may also present a somewhat formidable problem to the service engineer.

In the purely scientific sphere radio astronomy has undoubtedly taken the year's honours with the opening of the large steerable radio telescope at Jodrell Bank and the Mullard Observatory at Cambridge. Both of these events have been closely linked to the launching of the Russian earth satellites which has, without doubt, been the most outstanding scientific achievement of the year. Unfortunately little is yet known of the electronic equipment carried by these satellites but, from the evidence available, it would appear that the Russians are not so advanced as ourselves in this branch of science. But then, until the launchings took place, nobody, and most of all the Americans, would have conceded that the Russians had such a clear lead over the rest of the world in rocket propulsion.

From the foregoing brief résumé of the past year it may fairly be concluded that it has been a successful and prosperous one for our industry but that however great ones progress may be it does not pay to be complacent about ones achievements.

# Special Timing Techniques Employed on Guided Missile Ranges

By R. J. Garvey*, B.Sc.(Eng.)

*A central equipment consisting essentially of a crystal oscillator and a number of frequency dividing circuits provides timing and reference signals to the various measuring stations dispersed over a guided missile test range. The signals serve as time markers for the various recordings made and are also concerned with the control and firing of the missile.*

*A general description of the timer is given including the method of transmitting the timing pulses to the remote stations. One of the timer signals is coded so that elapsed time, with respect to an arbitrary zero, can be continuously marked on long runs of recording film.*

*Two equipments associated with the timer are concerned with the automatic control of the ground instrumentation during the launching and flight of the missile and with the control of a number of cine-theodolites. These will be described in later articles.*

IN flight testing guided missiles, performance data is recorded at a number of stations dispersed over the range while other stations are concerned with the control of the missile and associated equipment both before and during the flight. In general terms the instrumentation consists of:

Air to ground telemetry.

Radar trackers.

R.F. doppler system.

Cine-theodolites.

Cine-cameras.

Guidance and control system.

Firing circuits.

The measurements and control must be made with reference to an accurate and common time scale; a central timer accordingly supplies timing pulses to each station as shown by Fig. 1. This timer has two functions; it provides time makers for the various recording instruments and switching pulses which operate both recording and control instruments at specific times during a shoot.

Time markers are fed direct to the various recording stations, but switching pulses are supplied via a 'programme switch' as shown on Fig. 1. This unit employs uniselector switches which are stepped by a 1p/s signal from the timer; these switch the various range instruments on and off automatically during a shoot, according to a pre-arranged programme set up for the particular missile.

A clock in the range control room is driven by the timer; this counts off the seconds during a shoot, the times being announced at suitable intervals over the range communication loudspeakers by the control officer.

Cine-theodolites are used on the range to determine the trajectory and velocity of the missile. The cine mechanisms are triggered by timing pulses which are fed via a cine-theodolite controller. This controller phases the pulses from the timer so that the shutters of all the cine-theodolites operate in synchronism and at a regular rate.

Each flight test involves the subsequent analysis of many long runs of recording film. Normal time markers on the long records are not practical since it would be necessary to count 100 or 1 000p/s marks along the edge of the film over lengths of several hundred feet, in some cases, in order to relate the recorded events to the zero mark at the beginning of the film. Timing signals are therefore provided which are either marked off in decades to give a 'ruler' time scale or coded to give an indication of elapsed time with respect to the arbitrary zero.

Experience in the design of the timing equipment has shown that although it is necessary to have a central equipment it is not practical to meet every requirement of the range instrumentation with one comprehensive unit. To do so would result in a very complex unit, difficult to service and maintain; furthermore much of the equipment would become obsolete as range requirements change. The best arrangement is to design the timer to provide the more basic signals and to meet varied requirements as to the waveform, phasing, voltage and impedance level of the pulses with auxiliary equipment such as the programme switch and cine-theodolite controller. Such units can be modified or scrapped as range requirements change. Auxiliary units can be sited with the timer, or where convenient at the remote stations local to the particular instruments which they serve. A feature of the design which has proved useful is the provision of two central timing units,

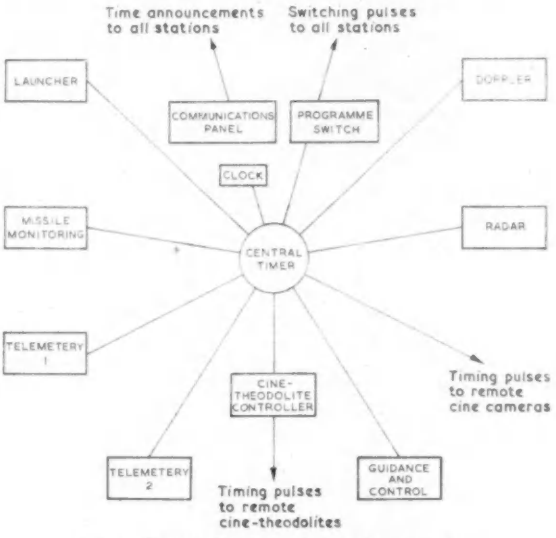



**Fig. 1. The central timer and range instrumentation**

* *The Royal Aircraft Establishment.*

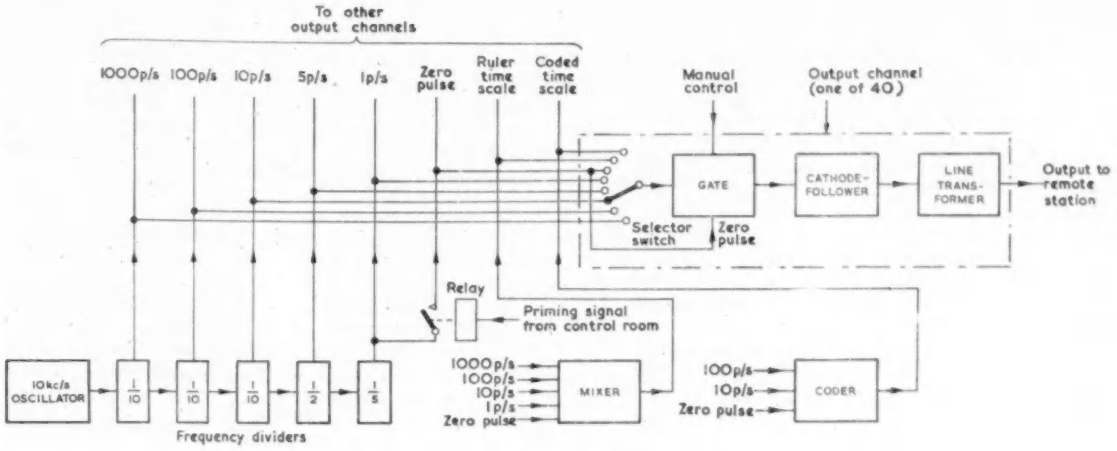



Fig. 2. Schematic diagram of the central timer

one serving as a stand-by in the event of a fault on the other. Extensive monitoring facilities are provided so that a fault is readily detected and the equipment switched out of service. These features are most important since a fault in the timer affects the whole range instrumentation.

Accuracy requirements for the timer are not very stringent. It is sufficient that the pulse repetition frequencies be correct to within ±0·01 per cent since performance measurements made on the missile, such as velocity evaluation, cannot be made in any case to better accuracy than ±0·1 per cent. What is most important is that the various events during a shoot can be co-related in time to within ±1msec. These requirements are met by deriving all timing pulses by division of a common crystal oscillator frequency.

This article is limited to a description of the basic timing equipment; the auxiliary equipment such as the programme switch and cine-theodolite control system will be described in later articles. The description refers to a specific installation; other equipments very similar to that discussed here are, however, installed at guided missile ranges both in Australia and the U.K. Much of the circuit design is conventional and is not described in detail; the time coding circuits are, however, original and are fully detailed.

## General Description

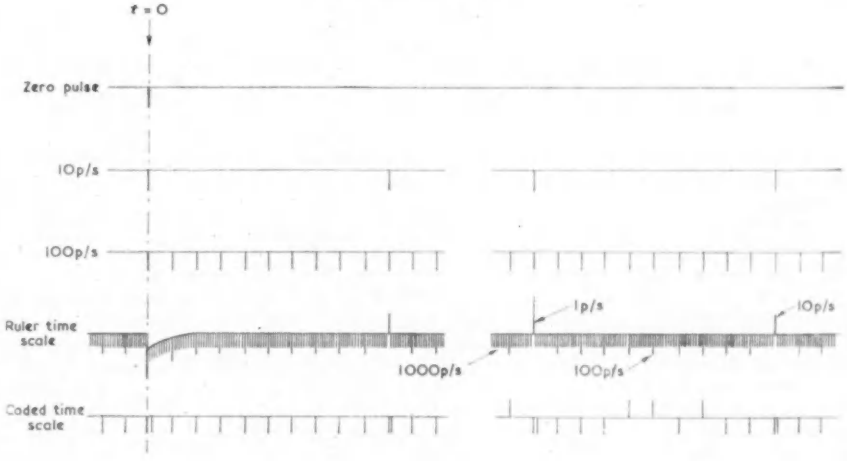
The complete system is shown by Fig. 2. It consists essentially of a 10kc/s crystal oscillator driving a series of dividing circuits which feed pulses at various frequencies to a number of output channels. There are 40 output channels identical with that shown, each one supplying a particular recorder or control equipment. The pulses are transmitted to the remote stations via underground telephone cables.

A gate in each output channel is opened just before the missile is launched so that the start of the transmissions represents zero time. Transmission before zero time can be effected by manual operation of the gates and the zero pulse which triggers them can also be selected and transmitted as a time signal. A relay operated from the control room selects one of the 1p/s pulses as a zero; this ensures that the zero is co-incident with a cardinal marker on all time scales so that it is unnecessary to add an end reading when annotating or analysing film recordings. It is important to mark the zero on all recordings since it is a common reference which permits the various data to be co-related in time.

An additional output is supplied by a mixer. This provides the ruler time scale shown on Fig. 3. It is a 1 000p/s signal with markers superimposed at 1, 10 and 100p/s. Zero time appears as a step in the composite waveform.

The function of the coder, shown on the schematic diagram, is to supply pulses that will serve as time markers and also indicate the elapsed time at any instant with respect to the zero pulse. A typical coded signal is shown by Fig. 12. The coded signal and ruler time scale are used

Fig. 3. Typical timing pulses



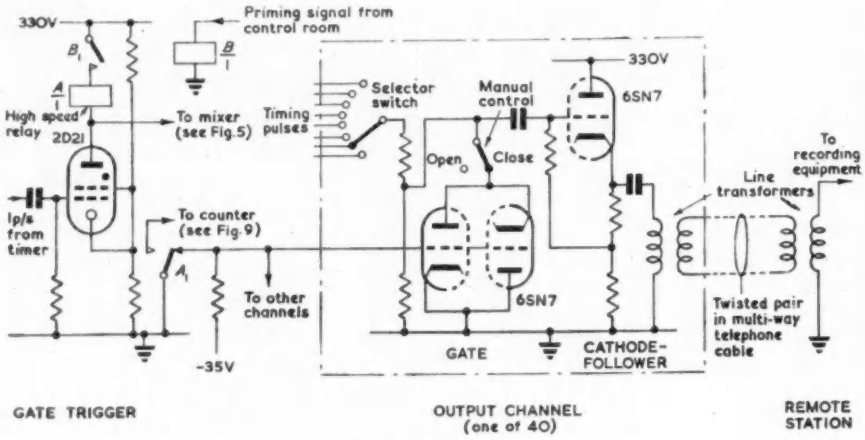



Fig. 4. Output channel

where long runs of recording film are involved. The coded time scale is also useful where recording equipments, such as target cameras, are switched on after zero time. It is impossible to record a zero mark under these conditions, but zero time is implied in the code so that the recordings can still be related in time to that of other instruments.

The frequency dividers each consist of four binary circuits, the division being reduced from 16 to 10 by feedback connexions. An additional output is taken from the last decade to give the required 5p/s signal. The circuit design of these dividers, and of the crystal oscillator, is conventional and will not be described here. Design details of the other circuits, in particular those of the coder, are given below.

### Output Channel

This is detailed by Fig. 4. There are 40 output channels, each one consisting of a selector switch, gate, cathode-follower and a Post Office type line transformer. The cathode-follower and line transformer effect the necessary impedance transformation for transmitting the signals along cables to the remote stations. The cathode-follower has an output impedance of about 400Ω which is reduced to 53Ω by the transformer.

The gate is a double triode with the grids strapped and connected via a relay contact to earth. In this condition signal pulses fed to the grid of the cathode-follower are shorted to earth; the left-hand triode removing positive and the right-hand triode negative pulses. When the relay contact is opened the grids are biased beyond cut-off; this opens the anode circuits and permits signal pulses to reach the cathode-follower. The gate can be opened manually by operating the switch shown in the anode circuit of the triodes. A necessary feature in the design of the gate circuit is its freedom from switching transients. A transient voltage, or change in d.c. level when operating the gate would be fed via the line transformers and would distort the output waveform.

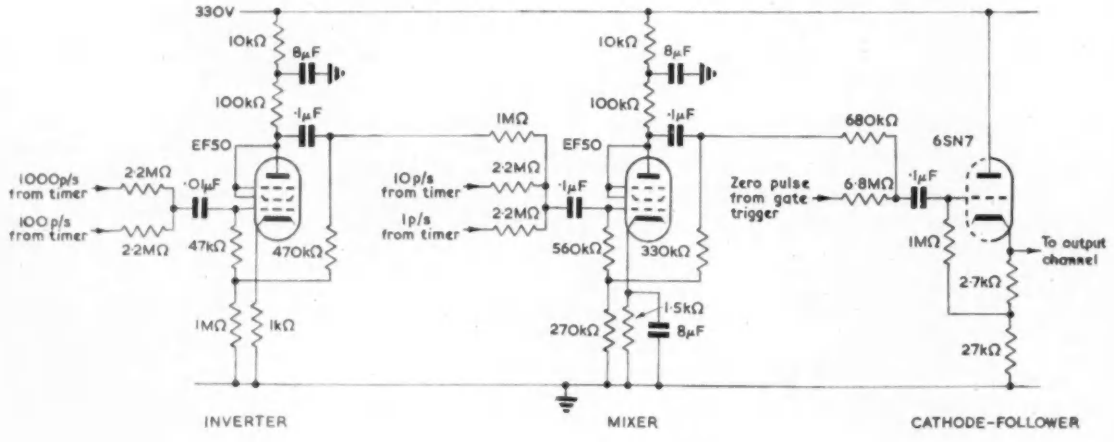
The gates in each of the output channels are operated by a common trigger circuit. This is a thyratron which is fired by one of the 1p/s pulses from the timer. When the thyratron is fired it operates a high speed relay which then removes the earth connexion from all the gate circuits. The thyratron is inoperative until the h.t. circuit is completed by another relay. The relay which primes the thyratron is normally switched on from the control room just before the missile is fired off the launcher. This priming relay is switched off when the flight is over so that the thyratron is reset and ready for another shoot.

### Line Transmission

Timing pulses are transmitted to the remote stations via underground telephone cables. These are 20lb, multi-core, lead sheathed cables; each pair of cores having the following characteristics:

Attenuation: 1 to 2·5dB/mile at frequencies of 1kc/s to 10kc/s.

Fig. 5. Mixer circuit which provides the ruler time scale



**Characteristic Impedance**: 450 to 170Ω at frequencies of 1kc/s to 10kc/s.

**Propagation Delay**: 10μsec/mile.

The longest cable run at present on the range is about 4 miles and it is possible to transmit the timing pulses over this distance without excessive attenuation, distortion or delay. Lines longer than 6 miles could involve the use of repeaters depending on the requirements of the remote equipment.

In addition to the timing pulses the multi-core cables carry speech signals and other pulse transmissions. All signals are carried over twisted pairs of lines which are terminated in transformers so that the signals and lines are balanced about earth potential. This eliminates crosstalk between the various transmissions; the attenuation between any two signals being greater than 50dB/mile.

The general transmission of pulses by radio has been considered, but this would involve the use of a multi-channel radio transmitter and a receiver at each remote station. The radio installation would, therefore, involve complex terminal equipment compared to that used with lines. It would be more difficult to service in the field particularly with radio receivers installed at remote and cross-country observation posts. With lines the terminal equipment is limited to line transformers and in some cases a.f. amplifiers at the receiving end. Radio transmission is justified when a line installation is impracticable or too expensive. It would be useful for seaward or very distant observation posts. With the range installation being described a single channel radio link is used only for transmitting pulses to a mobile observation post, where lines would be impractical.

## Mixer

This circuit provides the 'ruler' time scale and is illustrated by Fig. 5. Pulses at frequencies of 100 and 1 000p/s are fed from the decade dividers to the grid of the first valve. These pulses being inverted are added to the 1 and 10p/s pulses at the grid of the second valve. The composite signal is then fed via a cathode-follower to the 40 output channels. A zero pulse is added at the grid of the cathode-followers; this appears as a step in the composite waveform as shown by Fig. 3. Negative feedback is employed on the two amplifying valves to reduce the unwanted gain.

## Coder

### General Description

The function of the coder is to supply pulses that will serve as time markers and also indicate the elapsed time at any instant with respect to the zero pulse. A typical display of the coded time scale is given by Fig. 12. The pulses are spaced at 0·01sec intervals with a double pulse every 0·1sec. The groups of pulses between the double marks are read as binary numbers; a positive pulse being 1 and a negative pulse 0. The binary number indicates the number of tenth seconds that have elapsed up to the preceding 0·1sec marker. An alternative display is shown by Fig. 13. Here positive and negative pulses are replaced by dots and dashes; a dash being read as 1 and a dot as 0.

The general arrangement of the coder is illustrated by Fig. 6. Pulses at a frequency of 10p/s are fed via a gate to a nine stage binary counter. An electronic switch driven at a 100 steps per second scans the counter once after each operation. This scanning switch delivers an output pulse each time it sweeps across a counter that has been switched on.

The signal from the scanner is fed to a mixer where it is mixed with 10 and 100p/s signals to provide the required coded output; the mixing being illustrated by the waveforms of Fig. 11. The positive pulses from the scanner are twice the amplitude of the 100p/s pulses so that the two signals add to produce a positive pulse in the mixer output. The 10p/s signal is fed to the mixer via a delay circuit; it is then out of phase with the 100p/s signal and so produces double pulses in the output. Normally all pulses in the coder circuits are in phase since they are derived from the common 10kc/s oscillator and dividing circuits of the timing system.

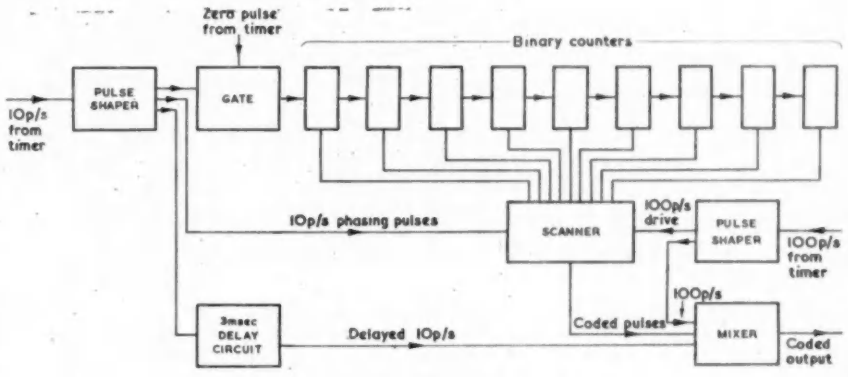



**Fig. 6. Schematic diagram of the coder**

The interpretation of the coded output signal follows from the fact that positive pulses indicate that certain binary stages are switched on at a particular instant; the position of the pulses with respect to the 0·1sec marker indicating which stages are concerned. Thus the groups of pulses between the double marks can be read as binary numbers, which indicate the number of tenth seconds that have elapsed up to the preceding 0·1sec marker. The elapsed time is measured from the instant at which the gate preceding the binary counter is opened. This gate is opened by a pulse coincident with zero time. Closing the gate at the end of the run resets the counter to the zero position; all the binary stages being switched to the off position.

The negative pulses shown in the output waveform are not strictly necessary for interpreting the code since the absence of a pulse could be read as 0. However, the absence of these pulses would result in long gaps in the time trace, the record would not be so convenient to read and interpolation would be necessary to measure to 0·01sec.

The scanner can be regarded as a ten-way rotary switch driven at 10 revolutions or 100 steps per second so that it rotates in synchronism with the 10p/s signal to the counter. Nine outlets of the switch are connected to the counter, the tenth being unused and serving as an idle position. A 10p/s signal phases the operation so that the switch reaches the idle position each time the counter is

operated. This phasing ensures that a complete and successive scan of the binary stages is made after each counter operation.

With the arrangement described, the coder counts up to 51·1sec and re-cycles. This meets most requirements at the range for which this equipment was designed since the flight time of missiles fired there rarely exceeds 30sec. The coder can, however, be used to count seconds rather than tenth seconds when the counter will have a capacity of 511sec.

The output signal from the coder is normally displayed as a time trace on c.r.o. recorders. With some recording equipment it is more convenient to record the time trace with a neon or argon filled flash lamp. The positive and negative pulses cannot be recorded as such on a single lamp so they are converted to square pulses which operate the lamp to produce a dash-dot time trace as shown by Fig. 13. Fig. 14 is a typical application where a dash-dot trace is recorded along the edge of a cine camera film. It is not practical to transmit the square pulses along the underground cables without excessive distortion; the conversion is therefore made by a small unit local to the particular recording equipment.

### Pulse Shapers

These circuits which are detailed by Figs. 7 and 8 shape the 10p/s and 100p/s pulses supplied from the external timing system so that they are suitable for operating the counter and scanner, both of which require fast, well defined waveforms. They also feed suitably shaped pulses into the mixer circuit.

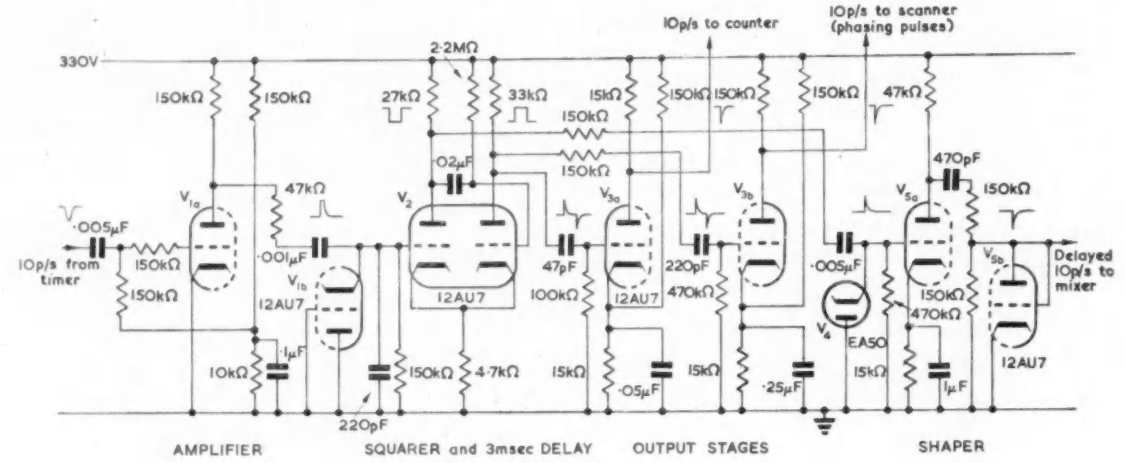



Fig. 7. 10p/s pulse shaper

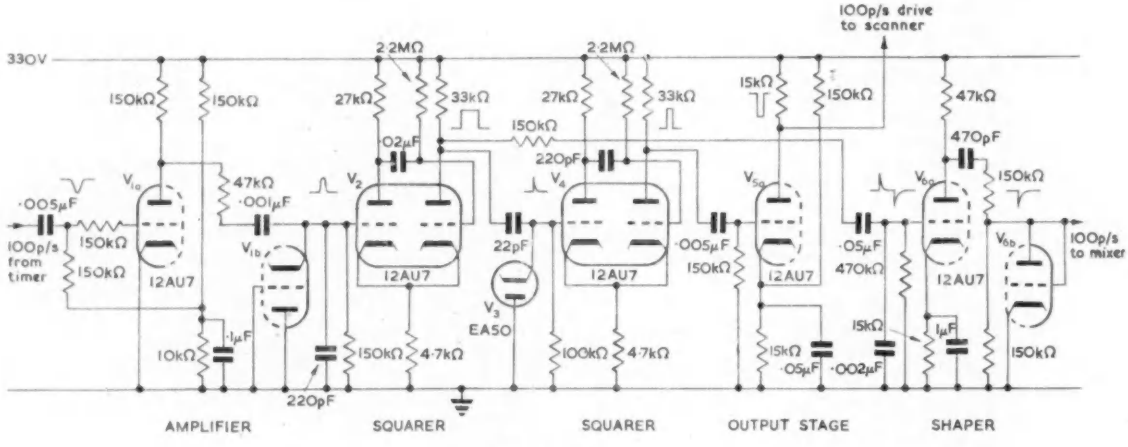



Fig. 8. 100p/s pulse shaper

The negative 10p/s pulses are fed to the grid of $V_{1a}$. This is positively biased so that it clips any small amplitude, unwanted signal from the input. The amplified pulses from $V_{1a}$ trigger a flip-flop; fast, square waves being available at the anode of $V_{2b}$. The diode connected to the grid of the flip-flop removes any negative component of the signal while the 220pF capacitor renders the flip-flop insensitive to any induced h.f. transients. The square waves at $V_{2b}$ are differentiated and fed to the amplifiers $V_{3a}$ and $V_{3b}$ which supply pulses to the counter and scanner. These amplifiers

are biased to clip off the negative pulses corresponding to the trailing edge of the flip-flop square waves. The 150kΩ resistor at the anode of $V_{2b}$ prevents the capacitive load of $V_{3b}$ spoiling the fast waveform required by the counter.

Negative square waves available at the anode of $V_{2a}$ are fed to the shaper $V_5$. Here the square waves are differentiated and the negative pips removed by the diode $V_6$. The 10p/s pulses at the anode of $V_{5a}$ coincide with the trailing edge of the square waves from $V_{2a}$ and they are therefore 3msec out of phase with the other 10 and 100p/s pulses. This circuit thus corresponds to the 3msec delay unit shown on the block diagram of Fig. 2. The network and diode connected to the anode of $V_{5a}$ differentiate and clip the output pulses again so that a suitably shaped signal is available for feeding to the mixer.

The 100p/s pulses are amplified by $V_{1a}$ and trigger the flip-flop $V_2$ as for the 10p/s signal. The square waves at the anode of $V_{2b}$ are differentiated and the negative pulses shorted by $V_3$. The remaining positive pulses trigger a second flip-flop $V_4$ which provides the 40$\mu$sec pulses for driving the scanner. These pulses are available at the anode of $V_{4b}$ where they have a peak amplitude of about 200V; they are fed to the grid of $V_{5a}$ which is biased to clip the top and bottom off the input square pulses. The amplifier also inverts the flip-flop output; negative pulses being required to drive the scanner.

The output at the anode of $V_{2b}$ is also fed to $V_{6a}$ which functions as an invertor so that negative-going square waves are available at the anode. The square waves are differentiated and the positive pulses removed by $V_{6b}$. The remaining negative pulses are fed to the mixer.

## Counter

This circuit which is shown on Fig. 9 is a conventional nine stage binary counter.

In the reset condition the left-hand resistance chain of each binary is connected via a common rail and a 4·7kΩ resistor to earth. This raises the grid potential of the right-hand triodes so that they remain in the conducting condition with the left-hand triodes cut-off; the 10p/s input signal is then ineffective. The counter starts to operate at zero time when the gate trigger relay, shown on Fig. 4, switches the reset rail to earth.

The neon lamps connected to each binary counter are mounted on the front panel of the equipment and give a useful indication of the counter operation; they are switched on and off by each binary stage.

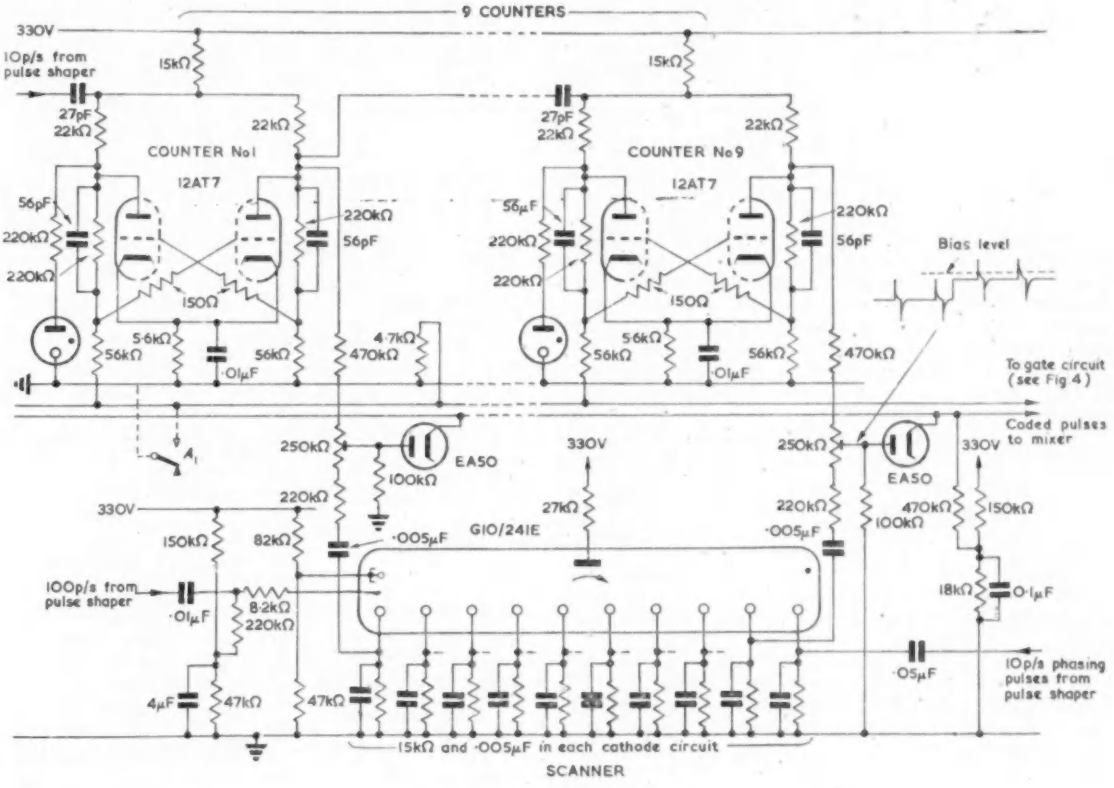



Fig. 9. Counter and scanner

## Scanner

This is also shown on Fig. 9. It is a cold-cathode glow discharge tube in which the anode to cathode discharge is switched to successive cathodes by suitable trigger pulses fed to the transfer electrodes[1]. The transfer electrodes are supplied in this case with a 100p/s signal so that the discharge rotates at a 100 steps or 10rev/sec.

Negative pulses at a frequency of 10p/s and coincident with those operating the counter are fed to the tenth cathode, overriding the normal operation and pulling the

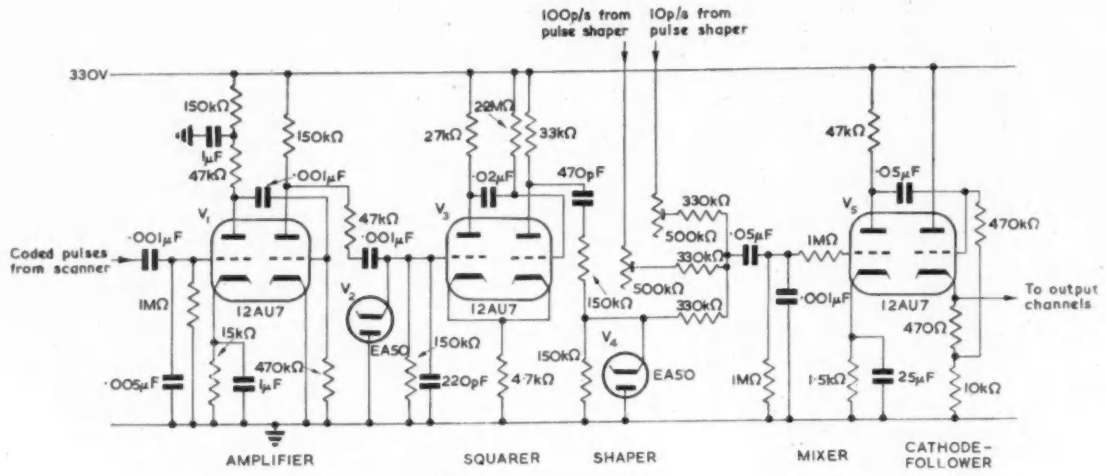



Fig. 10. Mixer and output stage

discharge to this cathode if it does not happen to be there when the counter operates. This phases the scanner so that a complete and successive scan is made after each counter operation. The phasing comes into effect when power supplies to the circuits are first switched on, it is then superfluous since the scanner rotates in synchronism with the counter until the equipment is switched off.

The current flowing successively through the 15kΩ resistors produces 10p/s pulses at each scanner cathode. The nine cathodes are connected respectively to the nine counter stages via a capacitor and resistance chain. A typical waveform for one of these connexions is shown. The square pulses at the cathode are differentiated and added to a platform voltage from the counter stage. The resulting waveform is fed via a diode to a common output rail. This diode is biased, by a d.c. voltage on the rail, so that pulses from the scanner cathode are only fed out when the particular counter stage is switched on. The resulting output is a train of pulses; the phase of each pulse showing which counters are switched on during each sweep of the scanner. A typical output for two successive scans is shown by Fig. 11.

The 250kΩ preset resistors in each resistance chain are used to adjust the signal amplitudes with respect to the bias voltage and thus balance out inequalities of valve characteristics and resistance values.

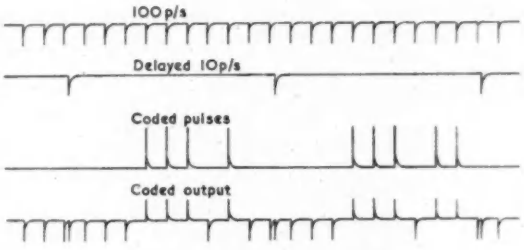



Fig. 11. Waveforms in mixer circuit

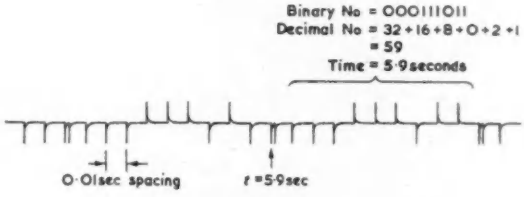



Fig. 12. Coded time scale

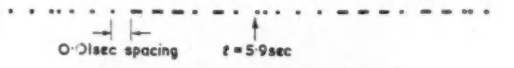


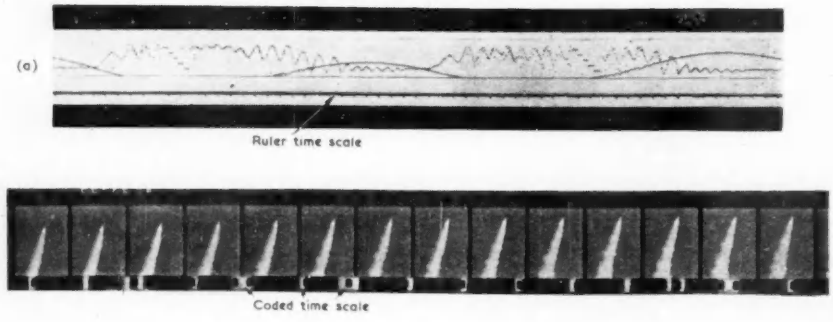

Fig. 13. Alternative coded time scale

### Mixer

This circuit is detailed by Fig. 10; its function is to shape the pulses delivered by the scanner and to mix them with the 10 and 100p/s signals.

The pulses from the scanner are amplified by $V_{1a}$ and $V_{1b}$ and then trigger the flip-flop $V_3$. The square pulses at the anode of $V_{3b}$ are differentiated, the negative pip removed with a diode and the positive one fed to the mixer $V_{5a}$. The 10 and 100p/s signals are added here as shown in Fig. 11. It will be seen that the coded pulses are twice the amplitude and of opposite polarity to the 100p/s pulses so

Fig. 14. Typical range recordings



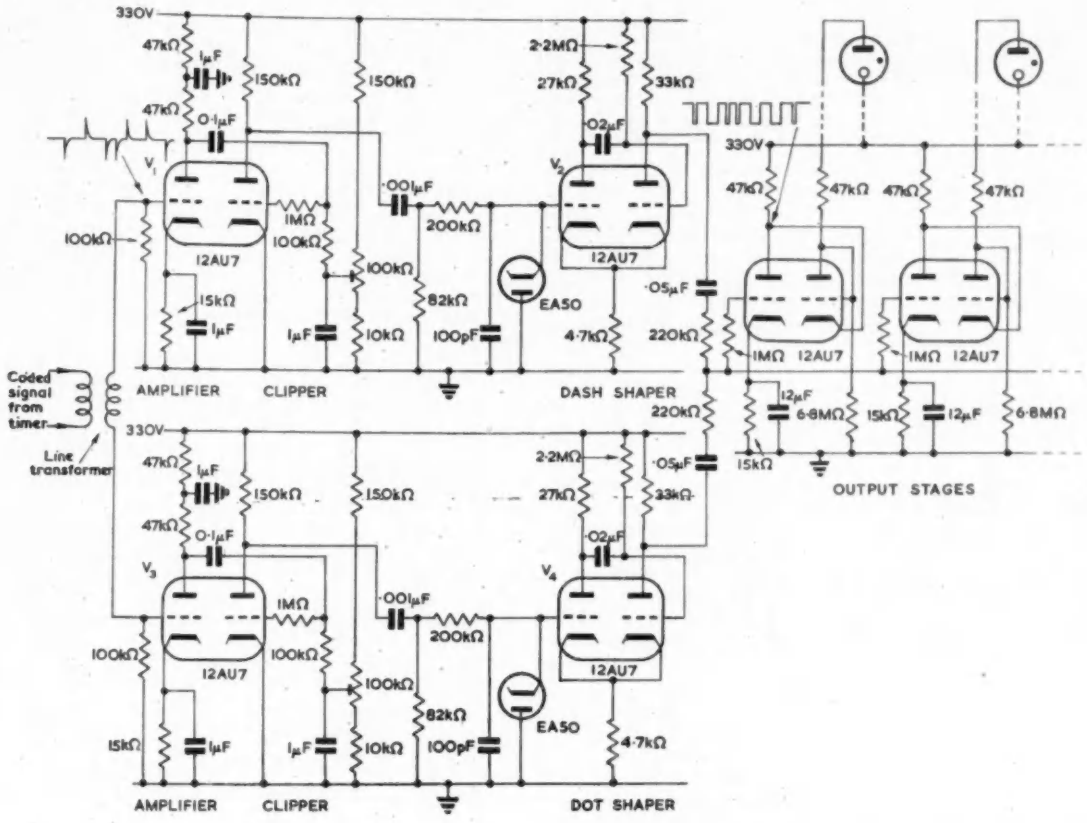



**Fig. 15. Local amplifier**

that the two signals add to produce positive pulses.

The coded pulses are adjusted to the required amplitude by the 500kΩ preset resistor shown. The 10p/s signal is out of phase with the other pulses and produces the double markers which bracket the pulses into groups of nine.

The shaping network connected to the anode of $V_{3b}$ and an identical circuit in the 100p/s pulse shaper ensures that the two sets of pulses have the necessary similar waveforms. Slight discrepancies in the waveform and phasing of the pulses are corrected by the capacitors connected to the grids of $V_{3a}$ (Fig. 10) and $V_{6a}$ (Fig. 8).

The capacitors shunted across the grids of $V_{1a}$ and $V_{3a}$ in the mixer circuit eliminate any h.f. transients coupled into the circuits; these would cause irregular operation of the flip-flop $V_3$.

The final coded signal at the anode of $V_5$ is fed via a cathode-follower to the output channels of the timer.

### Local Time Coder

As mentioned above it is convenient with some range equipment to record the time trace on a single neon or argon filled flash lamp. The positive and negative pulses of the 'coded' signal are therefore converted to square pulses which operate the lamp to produce a dot-dash time trace. It is not practical to transmit the square pulses along the underground cables to the remote recorder without excessive distortion; the conversion is therefore made by a small unit local to the recorder.

The circuit of this unit is detailed by Fig. 15. The equipment side of the line transformer is connected as a phase splitter so that a given signal pulse appears with opposite polarities at the grids of $V_{1a}$ and $V_{3a}$. The signal is amplified by $V_{1a}$ and fed to $V_{1b}$ which is biased to reject positive, and amplify, negative pulses. The positive pulses from the anode of $V_{1b}$ trigger the flip-flop $V_2$; this provides square pulses, each of 4msec duration, corresponding to the positive pulses fed to the grid of $V_{1a}$. The circuit, consisting of valves $V_3$ and $V_4$ operates in a similar manner to that just described. It operates, however, on pulses of opposite polarity, as seen on the line, and the flip-flop $V_4$ produces square waves of only 1msec duration.

The square waves from $V_2$ and $V_4$ are added and fed to the output valves. These amplify the signal so that it operates the neon recording lamps. The 6·8MΩ resistors keep the lamps ionized which improves the speed and reliability of their operation. The diodes isolate the driving and ionizing circuits. The unit is designed to operate timing lamps for three recording instruments if required.

Typical input and output waveforms are shown on the diagram; where the wide square waves correspond to negative and the narrow ones to positive input pulses. The time trace produced by the neon lamps is shown on the records of Fig. 13 and 14; the latter being a high speed cine camera film.

#### REFERENCE

1. Hough, G. H. and Ridler, D. S. Cold Cathode Glow Discharge Tubes, Part 3, *Electronic Engng*, *24*, 292 (1952).

# Continuous Recording of Waveforms on Photographic Film

By V. B. Hulme*, M.A.

*Limits to the information capacity of photographic film as a medium for recording electrical waveforms are examined. The limitations of the system using conventional cathode-ray tubes are discussed. The advantages of variable-area recording are pointed out, with particular reference to a new type of tube, in which the beam cross-section has a ribbon shape, producing a fluorescent line instead of a spot.*

*Using the new tube, various possible arrangements of the display are outlined. These include class-A push-pull, class-B push-pull, and the use of mirror images. It is concluded that whereas with conventional tubes the performance of the system is limited by the tube, with the new tube the limits set by the medium should be approached.*

IT is common practice to record electrical analogues of physical phenomena by photographing the fluorescent spot of a cathode-ray tube. The spot is deflected in sympathy with the electrical waveform, and the information is recorded in the form of the distance between the spot and a datum point on the line of deflexion. To record phenomena which are continuously variable, the film is moved continuously in a direction normal to the recorded deflexion, so that a graph is drawn of the variable on a time scale.

This method of recording arose naturally from the obvious convenience in merely putting together the cathode-ray oscilloscope and the cine-camera, two well-known pieces of apparatus, with the minimum of modification. The system has both advantages and disadvantages, when compared with other possibilities and different media; to discuss these is not the object of the present article, but rather to draw attention to the major limitations and, more particularly, to some interesting suggestions for improvement, employing a ribbon-beam cathode-ray tube[1].

### Limitations of the Deflected Spot System

The final limitations to the amount of detail or information which may be obtained from the recording ideally is given by the product of the resolution, or information capacity, of the film stock used in the camera, and the footage run. In practice, however, the film is not the limiting factor.

The number of elements into which the amplitude of the spot deflexion can be resolved, after recording, may depend on:

(a) The resolution of the film and the width of the track available for excursions of the spot image.

(b) The ratio of the tube spot diameter to the deflexion amplitude.

A typical fast negative film will resolve 30 lines/mm, a slow positive stock 100 lines. The track width available between sprocket holes on 35mm film is 25mm, so that between 1 500 and 5 000 amplitude elements can be resolved giving a maximum accuracy of 0·067 to 0·02 of 1 per cent of full deflexion. However, the best electrostatic-deflexion tubes have a spot diameter to maximum deflexion ratio of not less than 1/250, so that the amplitude resolution of the system is limited entirely by the tube, a figure which at best, assuming optimum focus and brightness, is a whole order coarser than the ideal limit imposed by the film.

* *E.M.I. Electronics Ltd.*

Even assuming, however, that a much improved tube could be made available, the ideal limit can never be approached with the deflected spot system, since the trace must have a minimum thickness in order to be detectable. A trace thickness of 0·016mm, corresponding to 30 lines/mm, would be practically invisible, and recovery of the information by electronic scanning systems would also be severely handicapped.

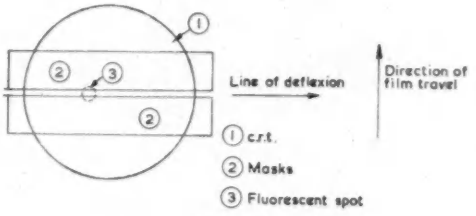



**Fig. 1. Masked c.r.t. display**

The number of independent elements which can be resolved per second of recording time, may depend on:

(1) The resolution of the film and the speed at which the film is propelled in the camera.

(2) The decay time of the phosphor.

(3) The effective width of the image of the spot in the direction of film movement.

The second factor may be dismissed with the observation that phosphors are readily available, as used in flying-spot scanning processes, with decay times less than 1 $\mu$sec and allowing up to $10^6$ elements/sec to be recorded without difficulty. Turning to the other two limiting factors, ideally the spot image should be equal to (or less than) the smallest element which the film can resolve, in order that the system performance should be limited only by the film and the speed of propulsion. This desideratum is rarely achieved in practice, but it is possible to mask the spot edges with plates having edges parallel to the line of deflexion, as in Fig. 1, and so to reduce the effective spot width as desired.

The velocity of propulsion is limited in continuous recording by practical considerations of bulk and cost only. Thus a typical camera employed for this purpose has a maximum speed of about 4m/sec, which gives $0{\cdot}4 \times 10^6$ elements/sec at a resolution of 50 lines/mm. Theoretically, however, a limit will be dictated by the necessity for ade-

quate exposure of the film, since exposure duration is inversely proportional to velocity. To evaluate this limit with a deflected spot system, allowance must be made for a large component of velocity due to deflexion. This increase in velocity due to deflexion may be determined by considering the maximum excursion of the spot during two elementary intervals of time, giving the maximum average velocity at which the position of the spot on the amplitude scale must be detectable at half-time $t_2$ (Fig. 2). Since it is assumed that system performance is limited by the film only, the elements have the same dimensions on the amplitude and time scales, and the increase in velocity is therefore given by $N/2$, where $N$ is the number of amplitude elements.

The duration of exposure $T$ is then given by

$T = 2d_1/NV$, where

$d_1$ = width of image

$V$ = velocity of film

and the product of the number of elements per second and the number of elements per track width, which is a

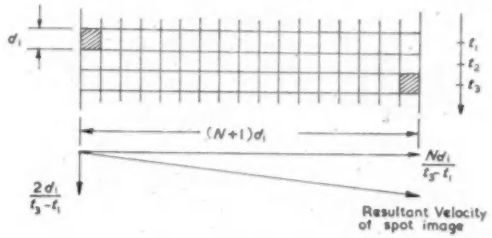



Fig. 2. Image velocity diagram

measure of the information capacity of the system, is given by

$NV/d_1 = 2/T$

Now $T = E/I = 4EF^2/\pi B$

where $I$ = image illumination

$F$ = f/No. of lens

$B$ = brightness of spot on tube face

$E$ = minimum exposure

giving

$NV/d_1 = \pi B/2EF^2$

neglecting loss of light in the lens and reduction of effective lens aperture due to the optical magnification, since these will lead only to small errors in practical cases[3].

Owing to the failure of the reciprocity law at short exposure times it is difficult to obtain a figure for the minimum exposure $E$, which must be considerably larger than in normal photographic practice. It is customary to evaluate emulsion speed in km/sec under specified conditions of tube operation and film development, assuming a lens aperture of $f/1$, for a trace density of 0·1 above fog level, i.e. for a trace which is barely perceptible. While a typical figure is 2km/sec, special methods applicable only to 'one shot' records of high speed transients have enabled writing speeds of several thousands of km/sec to be attained. For day-to-day recording of continuous phenomena a conservative figure must be taken, and it is found that with the maximum film velocity quoted for a typical camera (4m/sec), there is little scope for bandwidth extension by masking the spot, since this reduces the exposure below the minimum level. This would not be so, however, were it not for the reduction in effective exposure due to deflexion velocity.

Another considerable embarrassment is that the deflexion velocity varies from zero to a maximum several orders higher than that of the film, giving rise to exposure modulation in the ratio of the resultant image velocity to the film velocity. The intensity of the spot plotted against distance from the centre approximates the Gaussian probability law, so that the width of the recorded trace varies by an order or more with exposure, and it is consequently impossible to obtain optimum amplitude resolution over a large exposure range.

If the use of a ribbon-beam tube[1] in place of the conventional tube were to eliminate exposure modulation and all its disadvantages, the information capacity of the system would be extended by several orders.

## The Ribbon-Beam Tube

The ribbon-beam tube is described in detail elsewhere, but briefly the cathode area has been extended along a

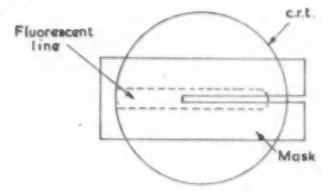



Fig. 3. Masked ribbon beam tube display

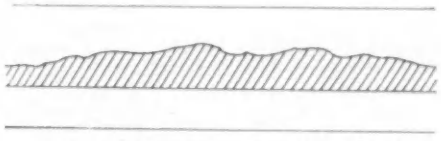


Fig. 4. Ribbon beam recording (film negative)

radial line, so that, without deflexion, a fluorescent line appears on the screen[1,2]. The intensity of this line at any point along its length is of the same order as that of a conventional tube spot. The beam is deflected in a direction parallel to the length of the line so that, in recording, the image of an elementary part of the line is replaced on deflexion, with that of another part, for the purpose of exposing an elementary film area, so that no exposure modulation can result, except in association with the end of the line. The information recorded is basically the position of the ends of the line with respect to a datum. Since the end of the line marks a transition from high to low intensity, it is convenient to limit the track width, by masking one side, so that the excursions of only one end of the line are accommodated, thus producing a variable area recording. The masked edge then forms a convenient datum line, and it is preferable that the mask should be on the cathode-ray tube so as to avoid errors due to camera vibration and lateral film movement. The edges of the line may also be masked as suggested for the deflected spot system, illustrated in Fig. 3. The form of the recording is shown in Fig. 4.

## Variable-Area Recording

The advantages of the variable-area form of recording are:

(1) The electrical waveform may be reproduced auto-

matically using simple apparatus (light source, optics and photocell).

(2) The information is recorded in the position of a density transition. The sharpness or slope of this transition is not limited as it is with a deflected spot system by the vanishing thickness of a line.

(3) Exposure modulation is reduced, if not eliminated, allowing optimum adjustment of exposure and extended information capacity.

Variable-area recordings have been made by deflecting the spot of a normal cathode-ray tube at a rate high compared to the velocity of the film and the maximum rate of deflexion due to the recorded signal. The line so produced can then be modulated either in length or in position[4,5,6]. Some of the advantages of variable-area recording are obtained with such methods, but it is plain that the effective exposure of the film is reduced (per unit area exposed) by the dissipation of the energy available from the tube spot over a larger area. However, it is possible to operate the tube under optimum conditions, since modulation of the exposure by the rate of change of input is reduced, and there is no risk of burning a hole in the phosphor when the latter is zero. This risk is a certainty when high intensity beams are used in a deflected spot system, unless arrangements are made to remove the spot from the screen.

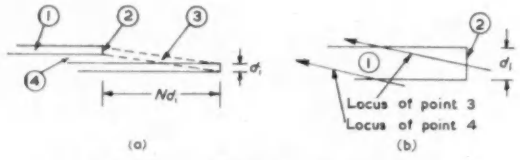



Fig. 5. Image velocity diagram, ideal ribbon beam

In a variable-area recording intended for electrical reproduction (e.g. of sound sequences) the photographic process is closely controlled so as to achieve the best overall system performance, and many subtleties enter into the determination of optimum values for the many variable parameters. In general the object is to produce a density transition across the track on the final print, from a value giving negligible attenuation to one giving negligible transmission, so that the emulsion characteristic is used only as an on-off device, and the photocell output is proportional to the area of unexposed track and not on variable parameters of the photographic process.

To assess the performance limits of such a system it is necessary to consider the brightness transition at the end of the fluorescent line on the tube, and the corresponding density transition produced on the film. There is no reason why the brightness transition should differ greatly from that for a conventional tube, following a radial line from the centre of the spot outwards. In the absence of modulation therefore it will be possible to locate the position of either the spot or the line with equal precision, if marked by the occurrence of the same arbitrary density transition in both cases. When the spot is deflected, however, the reference density may not be obtained at all, owing to velocity modulation, and certainly will not appear at the same distance from the trace centre. This applies even if velocity modulation does not carry the exposure out of the linear part of the film characteristic.

Consider now the image of a line (1) (Fig. 5) having a perfectly defined end (2), and of width $d_i$ equal to an amplitude element. Suppose a deflexion $Nd_i$ occurs in time $2d_i/y$. The exposure at the halfway point (3), assuming a constant deflexion velocity $Nv/2$, will be half that at the point (4), where no velocity occurs. The error in determining the position of the end of the line at the halfway point will be small, because the density transition on the film is produced by a wide exposure range, of the order of $1:2^7$. It can be shown by superposition methods that if the end of the line is imperfectly defined, the same reasoning applies, and the error due to deflexion velocity is no greater (Appendix 1).

Hence the variable-area system, using a ribbon beam tube, should have a great advantage over the deflected spot system, in that negligible velocity modulation results from deflexion. Consequently the bandwith of the system is not likely to be limited by a minimum film exposure, and the information capacity will be limited only by the film resolution.

### Multi-Channel Variable-Area System

In a multi-channel variable-area system, the mask at the unmodulated end of the fluorescent line can be replaced by a mirror surface in a plane normal to the line of deflexion, and parallel to the optical axis[7] (Fig. 6). The modulated end of the line must be placed between the mirror and the optical axis, so that it is not masked. The length of the mirror is made adequate to produce a reflected image of the line, but no larger, otherwise excessive safety gaps will be required between channels. This arrangement results in bilateral area modulation, and has the advantage that the exposure of the film is doubled by the reflected light. This advantage is nearly always valuable, e.g. by doubling the optical reduction and the width of the fluorescent line, a film stock can be used having less sensitivity and greater resolution.

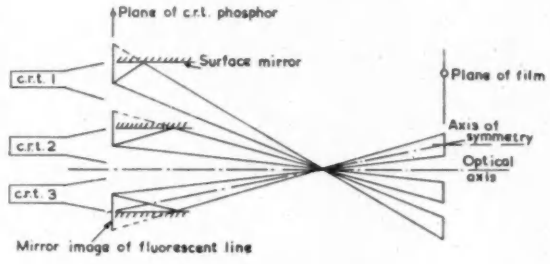



Fig. 6. Multi-channel variable-area recording system

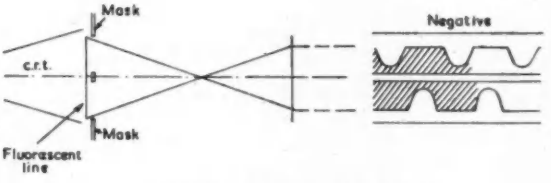



Fig. 7. Push-pull recording system

### Push-Pull Variable-Area Systems

When a high quality bi-directional (centre zero) channel is required, both ends of the fluorescent line can be used, producing push-pull variable-area tracks (Fig. 7). The fluorescent line is of constant length, and occupies a substantially central position in the absence of deflexion.

Deflexion modulates the area exposed on each half of the track which is presented to a pair of photocells, each being affected by one half of the track, their outputs being combined in antiphase. It is advisable to mask a small portion of the line in the centre, as shown, so that a safety gap is produced between the tracks, and small lateral movements of the film do not produce a spurious output. The advantage of the push-pull arrangement is that spurious components common to both channels are reduced or eliminated, including even harmonic distortion which might result from non-linear deflexion characteristics of the tube. The system described would be analogous to a class-A push-pull amplifier or modulator.

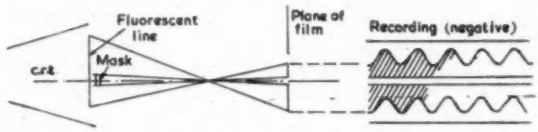



Fig. 8. Quiescent class-B push-pull system

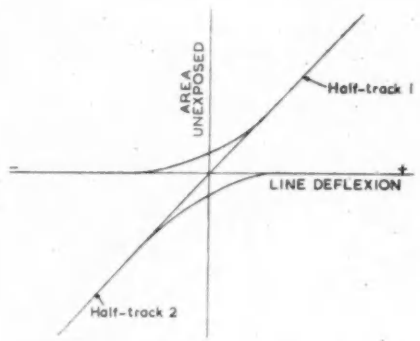



Fig. 9. Recording characteristic for system of Fig. 8

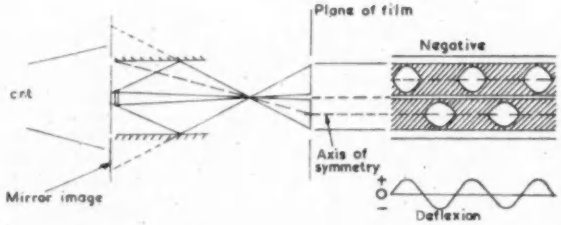



Fig. 10. Bi-lateral push-pull recording with mirrors

By masking the ends of the fluorescent line so that the space between the masks is just filled by the undeflected line, a quiescent class-B type system results. If the negative is used, as in Fig. 8, noise due to the exciter lamp, photocells and foreign matter adhering to the film, which forms a large part of the background noise in a film record replay, is proportional to the modulation (not constant) so that high signal-to-noise ratios are maintained at all modulation levels. Although the length of the line is critical in relation to the distance between the end masking plates, neither of these are likely to drift, once set up. Drift in the zero position of the line results in a d.c. output error only.

When the ends of the line are not clearly defined conditions are similar to those obtaining with a valve having a characteristic curved near cut-off. With the arrangement analogous to class-A operation, no distortion results if excursions are limited to the straight part of the characteristic. In the class-B push-pull arrangement, the curved part of the characteristic cannot be avoided, but distortion can be avoided if the masking is set up so that the curvature due to one end is compensated by that due to the other (see Fig. 9 and Appendix 2).

The advantages of the mirror arrangement can also be realized with class-B operation, by substituting mirrors for the masking plates at both ends of the line (Fig. 10). The film record takes the form of bilateral push-pull tracks (quiescent). Owing to the thickness of the glass of the tube face, the mirrors cannot reach the plane of the phosphor, and a small gap must be present in the centre of each bilateral track. It can be shown that distortion from this cause is avoided if the mirrors are placed so that the distance between them is the same as the length of the line (Appendix 3).

## Conclusions

It has been shown that there are serious fundamental limitations to the performance of the conventional cathode-ray trace recorder. These limitations can be more or less completely avoided by employing the ribbon-beam tube and variable-area techniques, performance then being limited only by the information capacity of the photographic medium. There appears to be no valid reason why the ribbon-beam tube should be appreciably more expensive than conventional tubes[1]. Future development will, however, depend on the relative popularity of the photographic medium and its competitors, a subject which has not been discussed. The trend is towards digital techniques, and if these can be applied to film recording so as to extend the information capacity of the medium, it is possible that superior performance and the advantage of a visible and more permanent record will ensure a future for this method of recording.

## Appendix 1

In Fig. 5(a) the deflexion of the line image (1) from one extreme position to the other was illustrated for a line having a sharply defined end (2). The deflexion occupied a time interval $(t_3 - t_1)$, during which the distance travelled by the film was twice the width of the line image $(2d_1)$. The exposure at the point (3), which is defined as the position of the centre of the line end on the trace at time $t_2$, assuming constant deflexion velocity, was seen to be half that at point (4), since $t_3 - t_1 = t_3 - t_2$. In Fig. 5(b) the moving line image was, for convenience, fixed in the diagram, and the locus of points (3) and (4) drawn as lines crossing the image.

Consider now a line having a graded brightness transition at the end. Such a line may be regarded as the resultant of a large number of lines having sharply defined ends, the ends being located in the neighbourhood of the gradient and distributed symmetrically in pairs about a point of half maximum brightness $b$, Fig. 11. Two of these overlapping lines are shown, having ends at $a$ and $c$, and the locus of the point (3) (Fig. 5) is drawn across the ends, the position at times $t_1$, $t_2$, $t_3$ being indicated.

Since ends $a$ and $c$ are symmetrically spaced about $b$, the lines contribute a mean exposure at point (3) equal to that from a line ending at $b$. There will be in fact an infinite number of such pairs distributed over the gradient, contributing a combined exposure at point (3) half that at point (4), Fig. 5. If the position of the line end (2) Fig.

5 is taken as that of the half maximum brightness point on the gradient, then the exposure at point (3) is the same as at point (2) in the absence of deflexion. Therefore the velocity of deflexion will not modulate the exposure, and no error will result from this cause in measuring the position of the 'end' of the line, when the end has a brightness gradient of the type postulated.

## Appendix 2

The conditions for linear class-AB push-pull operation

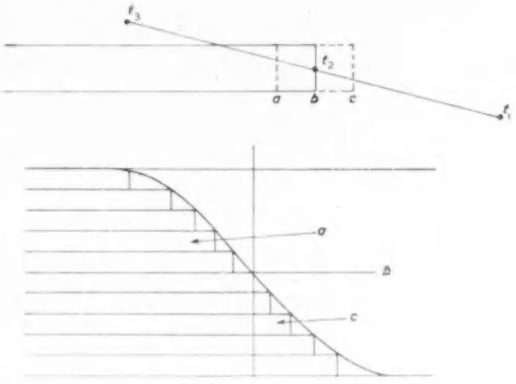



Fig. 11. Graded brightness transition

are easily found. Let the output from track (1) be an arbitrary function of deflexion $x$,

$$y_1 = F(x)$$

and that from track (2)

$$y_2 = F(-x)$$

For a linear balanced system the resultant output is

$$y_1 - y_2 = Kx$$

Expanding $F(x)$ in a power series

$$F(x) = a + bx + cx^2 + dx^3 + ex^4 + dx^5 \ldots.$$

But $F(x) - F(-x) = 2[bx + dx^3 + fx^5 \ldots.]$

$$= kx$$

$\therefore k = 2b$

and $d$, $f$ etc. $= o$

i.e. apart from a constant term and the term in $x$, odd powers of $x$ are excluded from $F(x)$. Similarly, even powers of $x$ are excluded from the slope of $F(x)$, $F'(x)$, which exhibits skew symmetry about $x = o$.

## Appendix 3

In a class-B quiescent push-pull system, both ends of the line must be masked. The length of the fluorescent line is critical, and must be equal to the distance between the end masks, so as to avoid a discontinuity in the characteristic at zero deflexion. When mirrors are used instead of end masks, the mirror surface cannot extend to the ends of the line since the thickness of the tube glass at the face intervenes.

Referring to Fig. 12, the mirror suface $EF$ fails to meet the line $OB$ by the distance $FB$. The light ray $BL$ meets the plane of the film, after passing through the lens $L$, at the centre of track (1). Owing to the gap $BF$, however, the division of the track into two parts $a$, $b$, exposed to the mirror image and the direct image respectively, is marked by a point (or line) somewhat off centre, where the direct ray $GFL$ and the reflected ray $HFL$ meets the film. Since $EF$ is normal to $OB$, $OB = BC$ and $HB = BG$.

Fig. 13 is a graph relating the unexposed area of the negative to the deflexion of the line from its central position (with the end at $B$). Curve $a$ indicates the contribution of the reflected image (on part $a$ of track (1)), and meets the zero area axis at $u$, which point corresponds to deflexion from $B$ to $H$. Curve $b$ gives the contribution of the direct image, meeting the zero area axis at $r$ corresponding to deflexion from $B$ to $G$.

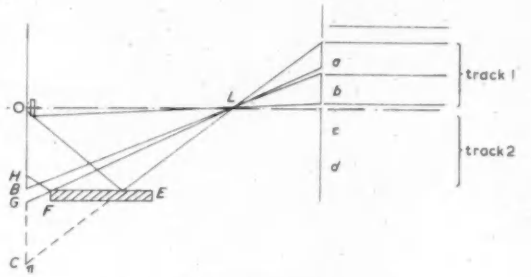



Fig. 12. Geometry of mirror optics

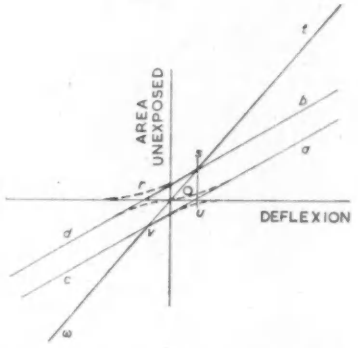



Fig. 13. Recording characteristic of system of Fig. 10

Similarly curves $c$ and $d$ indicate direct and reflected contributions to track (2) from the other half of the fluorescent line. If the geometry of the arrangement for track (2) has mirror symmetry with that for track (1), about the optical axis $OL$, then curves $c$ and $d$ meet curves $a$ and $b$ at $u$ and $r$ respectively and have the same slope, so that the overall push-pull characteristic is given by the straight line $w\,v\,o\,s\,t$.

In practice the ends of the fluorescent line have a finite brightness gradient. If the gradient conforms to that postulated in Appendix 1, and the distance between half brightness points at the two ends is made equal to the distance between the two mirrors, then a linear overall characteristic is obtained, although the curves representing individual contributions from parts $a$, $b$, $c$, $d$ deviate from linearity, as shown by the broken lines, near the zero area axis.

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# High Frequency Parameters of Transistors and Valves

By J. Zawels*

*High frequency equivalent circuits for thermionic valves in the common-cathode, common-grid and common-anode (cathode-follower) configurations are developed, analogous to the common-emitter, common-base and common-collector configurations of junction transistors. From these, the exact open-circuit (z), short-circuit (y) and hybrid (h) parameters for each of the above circuits are tabulated. The approximations permitted by the relative magnitudes of various elements are also indicated.*

THE behaviour of a device may be greatly clarified by using an equivalent circuit consisting of 'ideal' elements to represent it. In such a circuit approximations to simplify subsequent calculations may be made by inspection. If frequency dependent passive or active elements are introduced, however, the advantages of an equivalent circuit may be lost, since the behaviour of the circuit becomes obscured by the mathematical expressions describing the frequency dependence of the elements, and the use of the complex mathematical expressions for the open-circuit ($z$) of short-circuit ($y$) or hybrid ($h$) parameters[1], may in fact be simpler.

It is well known that at low frequencies the phase relationships in junction transistors and in vacuum triodes, (or in pentodes), are similar. The analogy exists between the base, collector and emitter electrodes on the one hand and the control grid, anode and cathode on the other. It would naturally be an advantage towards the understanding of the behaviour of both devices if their equivalent circuits could be made to correspond topologically. Indeed it was for this reason that a $\pi$ equivalent circuit was first proposed to represent the low frequency behaviour of transistors[2]. Because the phase relationships at higher frequencies differ, however, the equivalent circuits of the two devices are unlikely to correspond without the introduction of frequency dependent elements.

The primary object in deriving the equivalent circuits used in this article was to use only frequency independent elements[3,4]. It was also found that there are significant advantages in developing special circuits for the three modes of operation, viz. common-emitter, common-base and common-collector. Fortuitously, accurate valve circuits having topological resemblance to these circuits are possible. The use of special equivalent circuits with valves is also advantageous.

In this article the equivalent circuits of both junction transistors and valves are presented, and the exact $z$, $y$ and $h$ parameters of both devices are tabulated. Approximations which may be made as a result of differing impedance levels are also indicated.

### Triode at Low Frequencies

Fig. 1(a) shows a common-grid triode and Fig. 1(b) shows its conventional low frequency equivalent circuit which utilizes a fictitious generator. In practice this circuit is most useful in the analysis of common-cathode circuits.

For common-grid operation it will be shown that it is often advantageous to consider the generator and grid as a special three terminal device, as shown in Fig. 1(c). It is evident that this device has equal input and output currents and, for all terminations, has a voltage output which is a constant multiple ($\mu + 1$) times the input voltage. The usefulness of such a device, to be termed a $K$-amplifier[3,4], is that it has impedance transforming properties, and in this respect it can be treated as a conventional ideal two-winding transformer, with an impedance transformation ratio of $(\mu + 1) \equiv K$.

For the analysis of common-anode (cathode-follower) circuits, use is made of the impedance transforming properties of the $K$-amplifier by first transferring the anode resistance to the input side as shown in Fig. 1(d), its value now becoming $r_a/(\mu + 1)$. The $K$-amplifier is then replaced

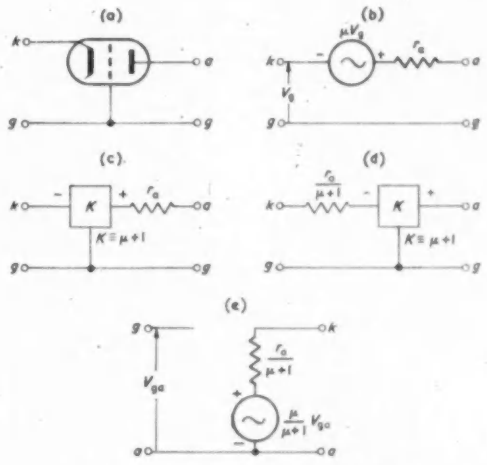


Fig. 1. Low frequency triode configurations

by a fictitious generator whose voltage $V_a$ refers to the new input terminals, and finally the resultant circuit is redrawn for convenience to obtain Fig. 1(e). It is seen that this circuit closely resembles the conventional circuit (Fig. 1(b)), but for cathode-follower analyses is considerably simpler.

### Triode at Medium and Very High Frequencies

For the high frequency case, consider complex impedances $z_a$, $z_{ag}$, and $z_{gk}$ to be present between the electrodes. The equivalent circuits for the three configurations shown in Figs. 2(b), 2(a) and 2(c), follow by extension from Figs. 1(b), 1(d) and 1(e) respectively. The elements of these impedances may be very accurately obtained, by comparing Fig. 2(b) with Fig. 3, which is the 'intrinsic' equivalent circuit of a triode, and applies from zero frequency up to that frequency where transit time is appreciable compared with the period of the impressed signal[5]. This circuit is referred to as the intrinsic circuit since it is only valid for the active part of the valve, i.e. the portion of the valve elements that intercepts electrons[6]. For the complete circuit inter-electrode capacitances $C_{ag}''$, $C_{gk}''$ and $C_{ak}''$ must be added in parallel with the electrodes, the lead inductances

* South African Iron & Steel Industrial Corporation Ltd.

in series with the electrodes. From the above, at very high frequencies, (neglecting lead inductance)

$$z_a = \frac{r_a}{1 + sr_a(C_{ak}' + C_{ak}'')} \quad \text{(1a)}$$

$$z_{ag} = \frac{1 + sC_{ag}'r_{ag}'}{s(C_{ag}' + C_{ag}'') + s^2r_{ag}'C_{ag}'C_{ag}''} \quad \text{(1b)}$$

$$z_{gk} = \frac{1 + sC_{gk}'r_{gk}'}{s(C_{gk}' + C_{gk}'') + s^2r_{gk}'C_{gk}'C_{gk}''} \quad \text{(1c)}$$

and

$$\mu' = \frac{\mu}{1 + sr_a(C_{ak}' + C_{ak}'')} \quad \text{(1d)}$$

where $s \equiv j\omega$. Note that the complex quantity $\mu'$ is used for convenience in tabulation, and arises out of the combination of $r_a$ and $(C_{ak}' + C_{ak}'')$ as a single impedance, $z_a$. In

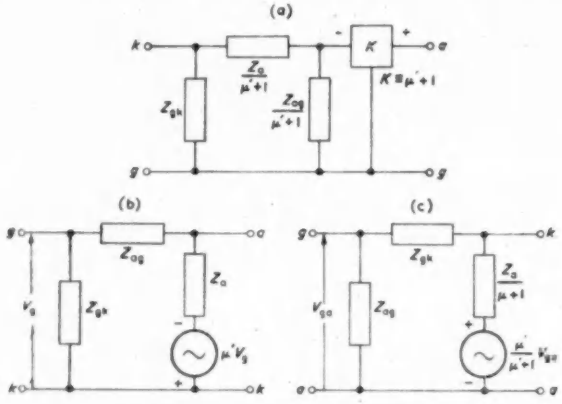


Fig. 2. High frequency triode configurations

the medium and low frequency ranges $r_{ag}' \ll 1/sC_{ag}'$ and $r_{gk}' \ll 1/sC_{gk}'$, and thus the above quantities simplify to

$$z_a = \frac{r_a}{1 + sr_aC_{ak}} \quad z_{ag} = (1/sC_{ag})$$

$$z_{gk} = (1/sC_{gk}) \text{ and } \mu' = \frac{\mu'}{1 + sr_aC_{ak}} \quad \text{(2)}$$

**Transistors**

The equivalent circuit of a junction transistor, termed the natural equivalent circuit[3], is shown in Fig. 4(a) and except for the presence of the element $r_{bb}'$ its topological resemblance to Fig. 2(a) is evident. As in Fig. 3, the inter-electrode capacitances and lead inductances have been neglected. However, if any of these are to be included, it should be noted that the collector-to-base inter-electrode capacitance is the most important, by virtue of an analogous Miller effect. Also, collector and emitter lead resistances have been neglected (of the two only the latter is of possible significance). Now, similarly to Figs. 1 and 2, Fig. 4(a) is most suitable for common-base, Fig. 4(b) for common-emitter, and Fig. 4(c) for common-collector analyses. Fig. 4(d) shows an alternative common-emitter circuit which is premised on the fact that generally for transistors in the useful frequency operating range $y_{11} \gg y_{12}$ and $y_{21} \gg y_{22}$[3,4]. (See also assumption (4a) below.) It has the advantage over Fig. 4(b) in that its fictitious generator is proportional to a terminal quantity, viz., the collector current $I_c$, whereas that of Fig. 4(b) refers to an internal quantity, viz. voltage $V_{b'e}$. On the other hand, however, it introduces two more elements, the current generator and the one-to-one phase reversing transformer.

The natural equivalent circuit elements are $r_{bb}'$, $C_c$, $g_e$, $C_c'$, $g_c'$, $r_d$, $L_d$ and $K$. The element $L_d$ is responsible for the common emitter short-circuit current amplification factor,

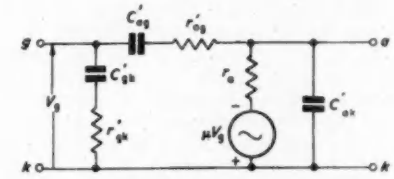

Fig. 3. Very high frequency intrinsic equivalent circuit for triode

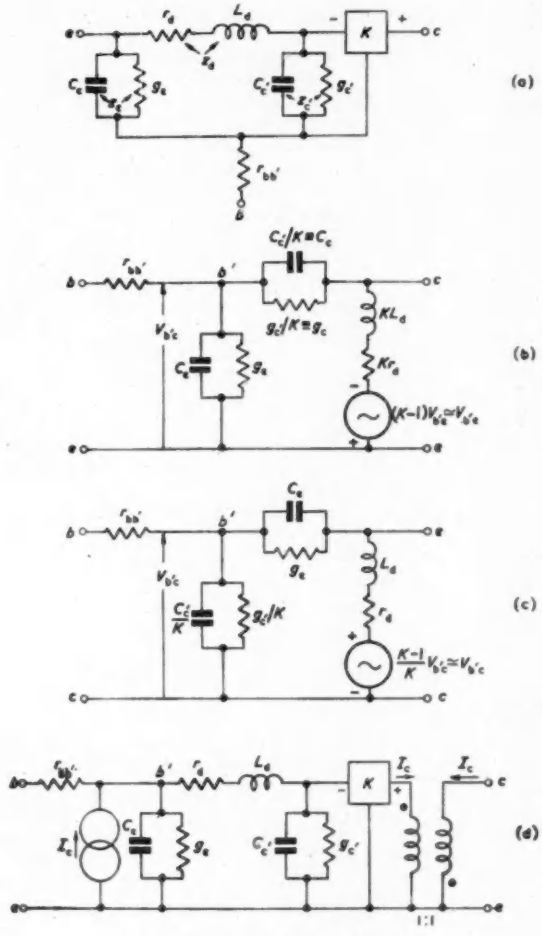


Fig. 4. Junction transistor configurations

$\alpha_{cb}$, being capable of a phase shift greater than 90°, and is of importance only at the highest frequencies of the useful frequency range. It is seen that in the configurations of Figs. 4(b) and 4(c) the quantities $C_c'/K$, $g_c'/K$ etc. appear. They arise from the impedance transforming properties of the $K$-amplifier and for convenience may be referred to as $C_c$ and $g_c$, respectively.

Due to the topological resemblance of the equivalent circuits of the thermionic and transistor triodes, any expression in terms of the parameters of the one, are easily converted to the other. Table 1 gives the exact expressions for the $z$, $y$ and $h$ parameters for transistors for the

common-emitter, common-base and common-collector modes of operation. The expressions are in terms of $r_{bb'}$, $z_e$, $z_{c'}$, $z_d$, and $K$ where ($s = j\omega$),

$$z_e = \frac{1}{g_e + sC_e} \qquad z_{c'} = \frac{1}{g_{c'} + sC_{c'}} \quad \text{and} \quad z_d = r_d + sL_d \qquad \ldots\ldots\ldots\ldots (3)$$

The usefulness of the concept of the $K$-amplifier in the common-base configuration is here illustrated by the fact that the $z$-parameters, for example, may be written down by inspection.

Table 3 applies to thermionic triodes and is easily derived from Table I, simply by letting $r_{bb'} = 0$, and replacing $z_e$ by $z_{gk}$, $z_d$ by $z_a/(\mu' + 1)$ and $z_{c'}$ by $z_{ag}/(\mu' + 1)$.

By utilizing the information on the relative magnitudes of the elements of a particular equivalent circuit, considerable simplification is possible. For example, in pentodes usually, $C_{ag} \ll C_{gk}$, and hence $z_{ag} \gg z_{gk}$. This may simplify some of the expressions in Table. 3. In transistors the following assumption may very often be made: $1/r_d g_e \gg 1$, $C_{c'} > C_e \gg C_{c'}/K$ $(= C_e)$, $1/g_e > r_{bb'}$, also $g_e$ and $g_c$ are of the same order of magnitude, while $K$ is a large number (varying from say 500 to 10 000). Thus $z_d$, $z_e$, $z_{c'}$ and $r_{bb'}$ are usually at most no more than one order of magnitude removed from each other. Thus the following (not necessarily mutually exclusive) expressions will hold:

$$K \gg |1 + (z_d/z_{c'})| \quad \ldots\ldots (4a)$$

$$K \gg |z_e/z_{c'}| \quad \ldots\ldots (4b)$$

$$K \gg \left|\frac{r_{bb'}(z_e + z_d + z_{c'})}{z_{c'}(z_e + z_d}\right| \quad \ldots\ldots\ldots (4c)$$

$$K \gg \left|\frac{r_{bb'}(z_e + z_d + z_{c'})}{z_{c'}z_e}\right| \quad \ldots\ldots\ldots (4d)$$

$$K \gg \left|\frac{z_e}{z_e + z_d}\right| \quad \ldots\ldots\ldots (4e)$$

$$K \gg \left|\frac{r_{bb'}z_e}{z_{c'}(r_{bb'} + z_e)}\right| \quad \ldots\ldots\ldots (4f)$$

Accordingly Table 2 gives the approximate expressions for the $z$, $y$ and $h$ parameters for transistors; the bracketed numbers indicate which of the above assumptions were made in the derivation of the particular parameter.

**TABLE 1. 'Exact' Z, Y and H parameters for transistors**

$[\Sigma \equiv Z_e + Z_d + Z_{c'};\ A \equiv KZ_{c'}(r_{bb'} + Z_e) + r_{bb'};\ B \equiv KZ_{c'}(Z_e + Z_d) + r_{bb'}\Sigma]$

| PARAMETER | | COMMON-EMITTER | | COMMON-BASE | | COMMON-COLLECTOR | |
|---|---|---|---|---|---|---|---|
| $z_{11}$ | $z_{12}$ | $r_{bb'} + \frac{Z_e(Z_d+Z_{c'})}{\Sigma}$ | $\frac{Z_dZ_e}{\Sigma}$ | $r_{bb'} + \frac{Z_e(Z_d+Z_{c'})}{\Sigma}$ | $r_{bb'} + \frac{Z_eZ_{c'}}{\Sigma}$ | $r_{bb'} + \frac{KZ_{c'}(Z_e+Z_d)}{\Sigma}$ | $\frac{KZ_{c'}Z_d}{\Sigma}$ |
| $z_{21}$ | $z_{22}$ | $\frac{Z_e[(K-1)Z_{c'}-Z_d]}{\Sigma}$ | $\frac{Z_d(KZ_{c'}+Z_e)}{\Sigma}$ | $r_{bb'} + \frac{KZ_eZ_{c'}}{\Sigma}$ | $r_{bb'} + \frac{KZ_{c'}(Z_e+Z_d)}{\Sigma}$ | $\frac{KZ_{c'}(Z_e+Z_d)-Z_eZ_d}{\Sigma}$ | $\frac{Z_d(KZ_{c'}+Z_e)}{\Sigma}$ |
| $y_{11}$ | $y_{12}$ | $\frac{KZ_{c'}+Z_e}{A}$ | $-\frac{Z_e}{A}$ | $\frac{B}{Z_dA}$ | $-\frac{r_{bb'}\Sigma+Z_eZ_{c'}}{Z_dA}$ | $\frac{KZ_{c'}+Z_e}{A}$ | $-\frac{KZ_{c'}}{A}$ |
| $y_{21}$ | $y_{22}$ | $\frac{Z_e[(K-1)Z_{c'}-Z_d]}{Z_eA}$ | $\frac{r_{bb'}\Sigma+Z_e(Z_d+Z_{c'})}{Z_eA}$ | $-\frac{r_{bb'}\Sigma+KZ_eZ_{c'}}{Z_dA}$ | $\frac{r_{bb'}\Sigma+Z_e(Z_d+Z_{c'})}{Z_dA}$ | $-\frac{KZ_{c'}(Z_e+Z_d)-Z_eZ_d}{Z_eA}$ | $\frac{B}{Z_eA}$ |
| $h_{11}$ | $h_{12}$ | $r_{bb'} + \frac{KZ_eZ_{c'}}{(KZ_{c'}+Z_e)}$ | $\frac{Z_e}{(KZ_{c'}+Z_e)}$ | $\frac{Z_dA}{B}$ | $-\frac{r_{bb'}\Sigma+KZ_eZ_{c'}}{B}$ | $r_{bb'} + \frac{KZ_eZ_{c'}}{KZ_{c'}+Z_e}$ | $\frac{KZ_{c'}}{KZ_{c'}+Z_e}$ |
| $h_{21}$ | $h_{22}$ | $\frac{Z_e[(K-1)Z_{c'}-Z_d]}{Z_e[KZ_{c'}+Z_e]}$ | $\frac{\Sigma}{Z_d(KZ_{c'}+Z_e)}$ | $\frac{r_{bb'}\Sigma+Z_eZ_{c'}}{B}$ | $\frac{\Sigma}{B}$ | $-\frac{KZ_{c'}(Z_e+Z_d)-Z_{c'}Z_d}{Z_d(KZ_{c'}+Z_e)}$ | $\frac{\Sigma}{Z_d(KZ_{c'}+Z_e)}$ |

**TABLE 2. Approximate Z, Y and H parameters for transistors**

*(For assumptions see equation (4))*

| PARAMETER | | COMMON-EMITTER | | COMMON-BASE | | COMMON-COLLECTOR | |
|---|---|---|---|---|---|---|---|
| $z_{11}$ | $z_{12}$ | $r_{bb'} + \frac{Z_e(Z_d+Z_{c'})}{\Sigma}$ | $\frac{Z_dZ_e}{\Sigma}$ | $r_{bb'} + \frac{Z_e(Z_d+Z_{c'})}{\Sigma}$ | $r_{bb'} + \frac{Z_eZ_{c'}}{\Sigma}$ | $\frac{KZ_{c'}(Z_e+Z_d)}{\Sigma}$ (c) | $\frac{KZ_{c'}Z_d}{\Sigma}$ |
| $z_{21}$ | $z_{22}$ | $-\frac{KZ_eZ_{c'}}{\Sigma}$ (a) | $\frac{KZ_{c'}Z_d}{\Sigma}$ (b) | $\frac{KZ_eZ_{c'}}{\Sigma}$ (d) | $\frac{KZ_{c'}(Z_e+Z_d)}{\Sigma}$ (c) | $\frac{KZ_{c'}(Z_e+Z_d)}{\Sigma}$ (e) | $\frac{KZ_{c'}Z_d}{\Sigma}$ (b) |
| $y_{11}$ | $y_{12}$ | $\frac{1}{r_{bb'}+Z_e}$ (b) | $-\frac{Z_e}{KZ_{c'}(r_{bb'}+Z_e)}$ (f) | $\frac{Z_e+Z_d}{Z_d(r_{bb'}+Z_d)}$ (c) | $-\frac{r_{bb'}\Sigma+Z_eZ_{c'}}{KZ_{c'}Z_d(r_{bb'}+Z_d)}$ (f) | $\frac{1}{r_{bb'}+Z_e}$ (b) | $-\frac{1}{r_{bb'}+Z_e}$ (f) |
| $y_{21}$ | $y_{22}$ | $\frac{Z_e}{Z_d(r_{bb'}+Z_d)}$ (a)(f) | $\frac{r_{bb'}\Sigma+Z_e(Z_d+Z_{c'})}{KZ_{c'}Z_d(r_{bb'}+Z_e)}$ (f) | $-\frac{Z_e}{Z_d(r_{bb'}+Z_e)}$ (d) | $\frac{r_{bb'}\Sigma+Z_e(Z_d+Z_{c'})}{KZ_{c'}Z_d(r_{bb'}+Z_d)}$ (f) | $-\frac{Z_e+Z_d}{Z_d(r_{bb'}+Z_e)}$ (f) | $\frac{Z_e+Z_d}{Z_d(r_{bb'}+Z_d)}$ (c) |
| $h_{11}$ | $h_{12}$ | $r_{bb'}+Z_e$ (b) | $\frac{Z_e}{KZ_{c'}}$ (b) | $\frac{Z_d(r_{bb'}+Z_d)}{Z_e+Z_d}$ (c) | $-\frac{Z_e}{Z_e+Z_d}$ (c) | $r_{bb'}+Z_e$ (b) | 1 (b) |
| $h_{21}$ | $h_{22}$ | $\frac{Z_e}{Z_d}$ (a)(b) | $\frac{\Sigma}{KZ_{c'}Z_d}$ (b) | $\frac{r_{bb'}\Sigma+Z_eZ_{c'}}{KZ_{c'}(Z_e+Z_d)}$ (c) | $\frac{\Sigma}{KZ_{c'}(Z_e+Z_d)}$ (c) | $1+\frac{Z_e}{Z_d}$ (b)(c) | $\frac{\Sigma}{KZ_{c'}Z_d}$ (b) |

**TABLE 3. Exact Z, Y and H parameters for vacuum tube triode**

$[\Sigma \equiv (\mu' + 1)Z_{gk} + Z_a + Z_{ag};\ \mu' = \mu Z_a/r_a]$

| PARAMETER | | COMMON-CATHODE | | COMMON-GRID | | COMMON-ANODE | |
|---|---|---|---|---|---|---|---|
| $z_{11}$ | $z_{12}$ | $\frac{Z_{gk}(Z_a+Z_{ag})}{\Sigma}$ | $\frac{Z_aZ_{gk}}{\Sigma}$ | $\frac{Z_{gk}(Z_a+Z_{ag})}{\Sigma}$ | $\frac{Z_{gk}Z_{ag}}{\Sigma}$ | $\frac{Z_{ag}[Z_{gk}(\mu'+1)+Z_a]}{\Sigma}$ | $\frac{Z_{ag}Z_a}{\Sigma}$ |
| $z_{21}$ | $z_{22}$ | $-\frac{Z_{gk}(\mu'Z_{ag}-Z_a)}{\Sigma}$ | $\frac{Z_a(Z_{ag}+Z_{gk})}{\Sigma}$ | $\frac{Z_{gk}Z_{ag}(\mu'+1)}{\Sigma}$ | $\frac{Z_{ag}[Z_{gk}(\mu'+1)+Z_a]}{\Sigma}$ | $\frac{Z_{ag}(\mu'Z_{gk}+Z_a)}{\Sigma}$ | $\frac{Z_a(Z_{ag}+Z_{gk})}{\Sigma}$ |
| $y_{11}$ | $y_{12}$ | $\frac{1}{Z_{ag}} + \frac{1}{Z_{gk}}$ | $-\frac{1}{Z_{ag}}$ | $\frac{(\mu'+1)}{Z_a} + \frac{1}{Z_{gk}}$ | $-\frac{1}{Z_a}$ | $\frac{1}{Z_{ag}} + \frac{1}{Z_{gk}}$ | $-\frac{1}{Z_{gk}}$ |
| $y_{21}$ | $y_{22}$ | $\frac{\mu'Z_{ag}-Z_a}{Z_aZ_{ag}}$ | $\frac{1}{Z_a} + \frac{1}{Z_{ag}}$ | $-\frac{\mu'+1}{Z_a}$ | $\frac{1}{Z_a} + \frac{1}{Z_{ag}}$ | $-\left(\frac{\mu'}{Z_a} + \frac{1}{Z_{gk}}\right)$ | $\frac{(\mu'+1)}{Z_a} + \frac{1}{Z_{gk}}$ |
| $h_{11}$ | $h_{12}$ | $\frac{Z_{ag}Z_{gk}}{Z_{ag}+Z_{gk}}$ | $\frac{Z_{gk}}{Z_{ag}+Z_{gk}}$ | $\frac{Z_aZ_{gk}}{(\mu'+1)Z_{gk}+Z_a}$ | $\frac{Z_{gk}}{Z_{gk}(\mu'+1)+Z_a}$ | $\frac{Z_{ag}Z_{gk}}{Z_{ag}+Z_{gk}}$ | $\frac{Z_{ag}}{Z_{ag}+Z_{gk}}$ |
| $h_{21}$ | $h_{22}$ | $\frac{(\mu'Z_{ag}-Z_a)Z_{gk}}{(Z_{ag}+Z_{gk})Z_a}$ | $\frac{\Sigma}{Z_a(Z_{ag}+Z_{gk})}$ | $-\frac{(\mu'+1)Z_{gk}}{(\mu'+1)Z_{gk}+Z_a}$ | $\frac{\Sigma}{Z_{ag}[Z_{gk}(\mu'+1)+Z_a]}$ | $-\frac{(\mu'Z_{gk}+Z_a)Z_{ag}}{(Z_{ag}+Z_{gk})Z_a}$ | $\frac{\Sigma}{Z_a(Z_{ag}+Z_{gk})}$ |


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# A Very High Speed Precision Tachometer

By J. K. Goodwin*, A.Inst.E.

*The development of new high speed counting tubes prompted the design of this instrument. Although it is used mainly as a tachometer it may also be used as a general purpose frequency measuring instrument of high accuracy.*

IN 1954 Bland and Cooper[1] described an integrating type of tachometer capable of reading up to 80 000rev/min in two decade steps.

After gaining considerable experience with this tachometer it was decided to develop another similar instrument which would be portable and as small as possible consistent with ease of servicing. The first tachometer was housed in a console as part of an installation.

Since the first tachometer was built new counter tubes have been developed having a maximum counting rate of 20 000p/s. The instrument described in this article will count up to 40 000rev/min with the extra decade step giving 400 000rev/min. The tachometer has been designed bearing in mind that it is possible to use the instrument for numerous applications. The instrument may also be used as a counter, counting up to 20 000p/s to an accuracy of ±1p/s or 200 000 ±10p/s and for counting random pulses over any time period up to a maximum number of 999 999. An external timing circuit can be used with the instrument to provide counting for periods other than the 1 and 2sec provided by the internal timing source. The circuit operation is still exactly as stated for this latter use. The accuracy limitation is inherent in this type of counting equipment because of the necessity for sampling the input signal by means of some form of gate.

*The complete tachometer*

**Basic Operation**

The overall circuit operation is very similar to the previous tachometer. Briefly the operation is as follows: input pulses are applied to a gating pentode, controlled by an accurately known timing source. The input pulses from the gate are passed to a series of Dekatron counting tubes. After the pulses have been displayed on the counting tubes for a certain time, the Dekatron 'glows' are returned to zero ready for the action to begin again. The circuit will be described from the block schematic diagram shown in Fig. 1.

INPUT AND LIMITING STAGE (Fig. 2)

The requirements of the input circuit are as follows: the input voltage shall be reasonably low in order that the instrument will be versatile and not normally require external pre-amplifiers. The input impedance must be high over the entire frequency range covered by the instrument.

A double triode ($V_8$) is used for the input amplifiers, one half as a class-A amplifier and the other half as a cathode-follower. The overall response of $V_8$ is 3dB down at 1·6c/s and 180kc/s. A minimum input of 1·5V peak-to-peak is required to operate the counter. The maximum input voltage should be limited to 10V. $R_{42}$ is included in the circuit in order that the signal source is not loaded should $V_{8a}$ be driven into grid current by excessive input voltage.

$V_{8a}$ is *RC* coupled to $V_{8b}$ and operated under near cut-off conditions as a cathode-follower. The output from the cathode-follower is positive going and feeds a Schmidt trigger which produces a rectangular wave with a very short rise-time.

In order to produce a rectangular waveform of very short rise-time it is necessary that the trigger valve is driven hard into its unstable state, that is grid current is drawn by $V_{9a}$ and by $V_{9b}$ during the period when the circuit is changing from its unstable to its stable state. The action of the circuit is as follows: in the stable state it is arranged so that $V_{9a}$ is cut off by the voltage developed across $R$ and $V_{9b}$ is conducting.

Resistors $R_{50}$ and $R_{51}$ form a potential divider so that when $V_{9a}$ is cut off then the grid of $V_{9b}$ is at cathode potential and taking a small amount of grid current.

As the cathode potential of $V_{8b}$ rises it takes the grid of $V_{9a}$ with it and at some point during this rise the grid potential of $V_{9a}$ becomes sufficiently positive to allow $V_{9a}$ to conduct; as $V_{9a}$ begins to conduct the voltage across $R_{48}$ increases and the grid voltage of $V_{9b}$ falls. The action is cumulative and continues until $V_{9b}$ can no longer conduct and it becomes cut-off and $V_{9a}$ is conducting.

It will be clear from Fig. 3 and the circuit description that the width of the output wave from the trigger will vary with the input pulse width and amplitude. This is of no importance however, since the output from the trigger is differentiated by $C_{29}R_{53}$ and the negative going pulse is removed by the shunt diode across $R_{53}$. Then the output is fed directly to the gating valve; or the output is fed via $C_{25}$ and $R_{56}$ when the trigger output is connected to the scale of ten divider. In the latter case, however, the negative pulses are used to trigger an Eccles-Jordan divider, the positive pulses being removed by the diodes in the binary dividers.

The rise-time of the rectangular wave from the trigger is approximately 1$\mu$sec. By switch selection the output from the trigger can be fed to either the scale of ten divider or direct to the gating valve.

SCALE OF TEN DIVIDER

The divider consists of four Eccles-Jordan binary

* *The Brush Electrical Engineering Company Limited.*

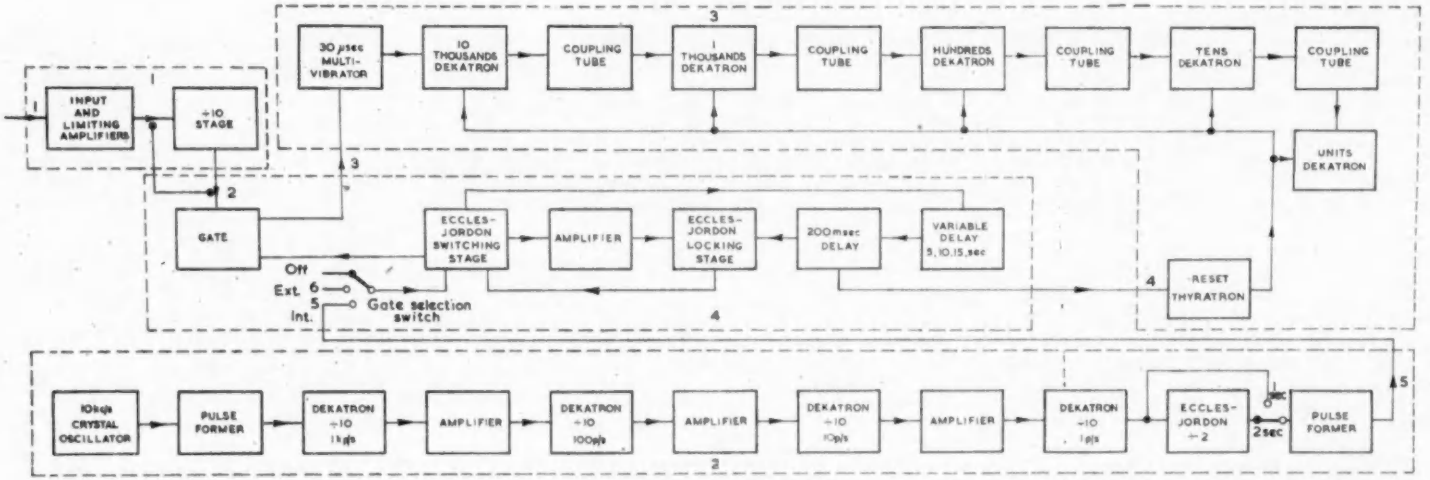



Fig. 1. General arrangement of the tachometer

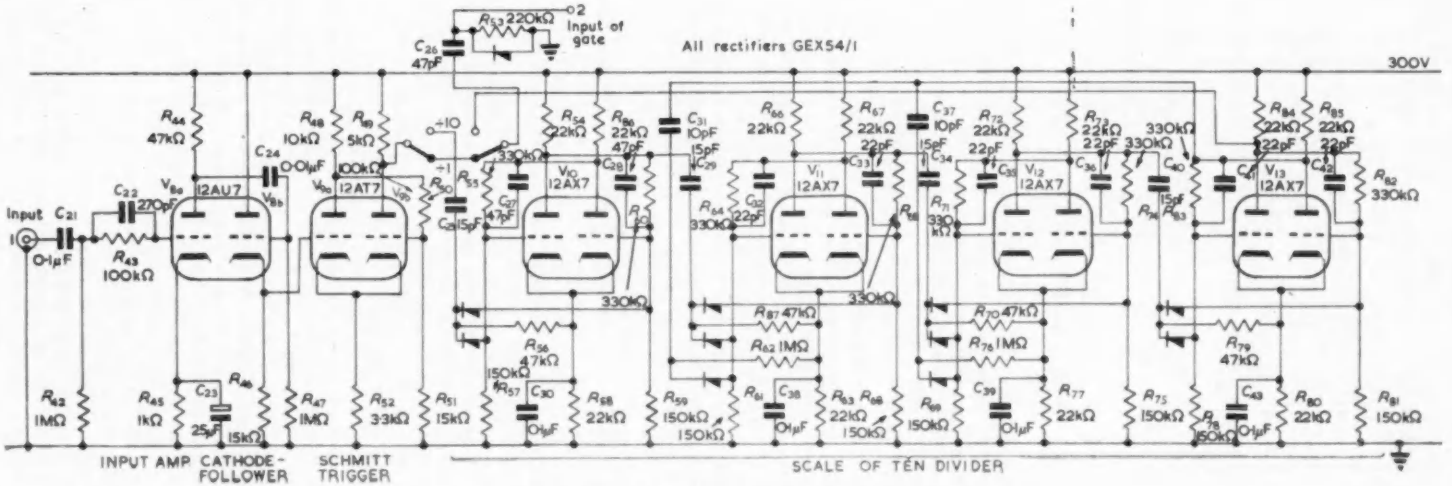



Fig. 2. Input and limiting stage—scale of ten divider

dividers connected in cascade, this arrangement gives a division ratio of 16. By suitable feedback loops the division ratio is reduced to 10. The circuit will operate up to a maximum frequency of 500kc/s. When the divider is operating correctly the operating code is as follows:

| | | | |
|---|---|---|---|
| (0) | 0000 | (5) | 0101 |
| (1) | 0001 | (6) | 0110 |
| (2) | 0010 | (7) | 0111 |
| (3) | 0011 | (8) | 1110 |
| (4) | 0100 | (9) | 1111 |

Where the left-hand digits represent the number of input

Fig. 3. Grid and anode waveforms of $V_9$

pulses and the right-hand row represent the valve or valves which are conducting for a given number of input pulses.

From the input and limiting stage and the scale of ten divider there is now a series of pulses corresponding to either the input signal or one-tenth of the input which can be fed into further stages of the tachometer

TIMING PANEL (Fig. 4)

The purpose of this unit is to provide accurate timing pulses for operating the gate.

The accuracy of the whole instrument depends on this unit and it is of paramount importance that it is unfailing in its accuracy and reliability.

The whole unit has been completely re-designed, a 10kc/s crystal is used as the frequency standard instead of a 100kc/s crystal which was previously used. This simplifies the divider considerably and reduces the number of valves used in the unit.

A variable-mu pentode ($V_{14}$) is used as the drive source for the crystal. The output from the valve is amplitude controlled by means of a voltage developed across a crystal diode. The stage is operated at a very low voltage (50V) as well as having the amplitude control to prevent the crystal being overdriven and damaged. $C_{44}$ is used to 'pull' the crystal to an accurate 10kc/s; this is necessary since the crystal is cut to an accuracy of 0·005 per cent and this tolerance would cause inaccuracies particularly at high frequencies. The crystal frequency being set up with the aid of a valve maintained tuning fork.

The output from the crystal oscillator stage is fed into the cathode-follower to prevent loading of the oscillator. This cathode-follower drives an amplifier which is normally conducting hard. Positive going pulses from the anode of $V_{15b}$ cause $V_{16a}$ grid to rise and $V_{16a}$ conducts. Negative going pulses from this valve drive the first Dekatron divider, a high speed type Ericsson GC10D dividing from 10kp/s to 1kp/s. Three sub-miniature Dekatron tubes reduce the 1kp/s pulses to 100p/s, 10p/s and 1p/s. In the future it is hoped to replace the hard valve coupling between the GC10D's by trigger tubes to reduce h.t. consumption and heater current.

Pulses of 1sec duration from the last divider ($V_{23}$) are fed either direct to a one-shot multivibrator ($V_{25}$) pulse forming stage, or through an Eccles-Jordan divider ($V_{24}$) and then to the multivibrator. Thus pulses of either 1 or 2sec repetition frequency at a constant pulse width are available. This unit will provide a very accurate frequency standard which may be used for other purposes in the laboratory.

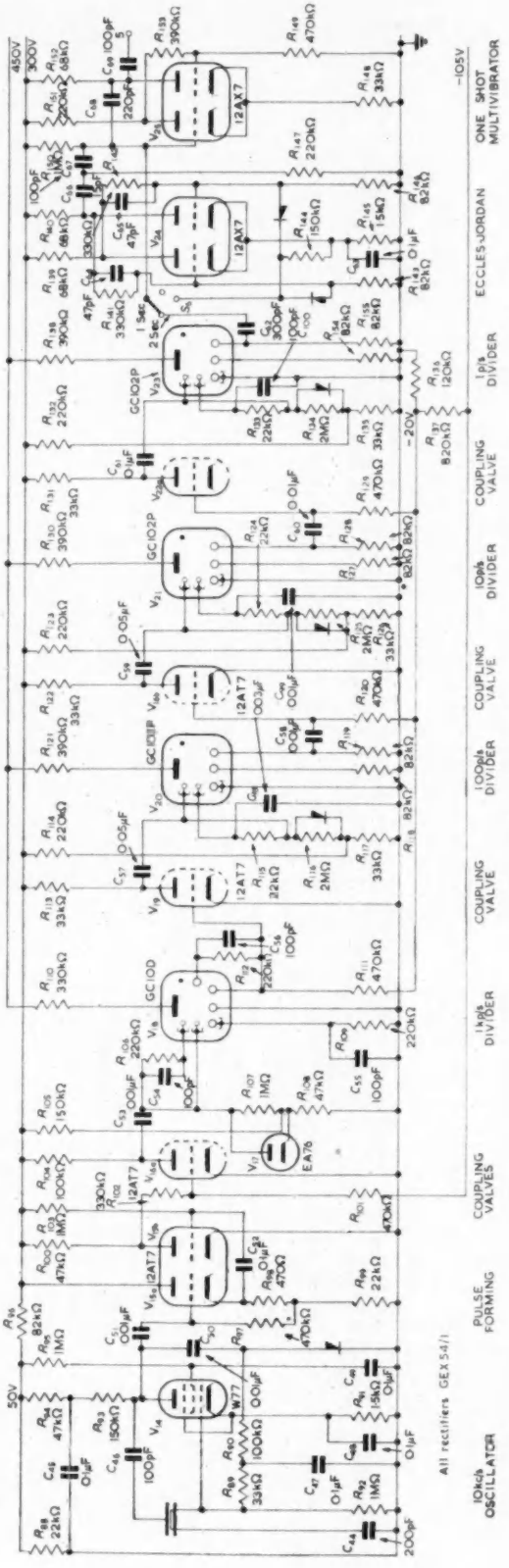



Fig. 4. Timing panel

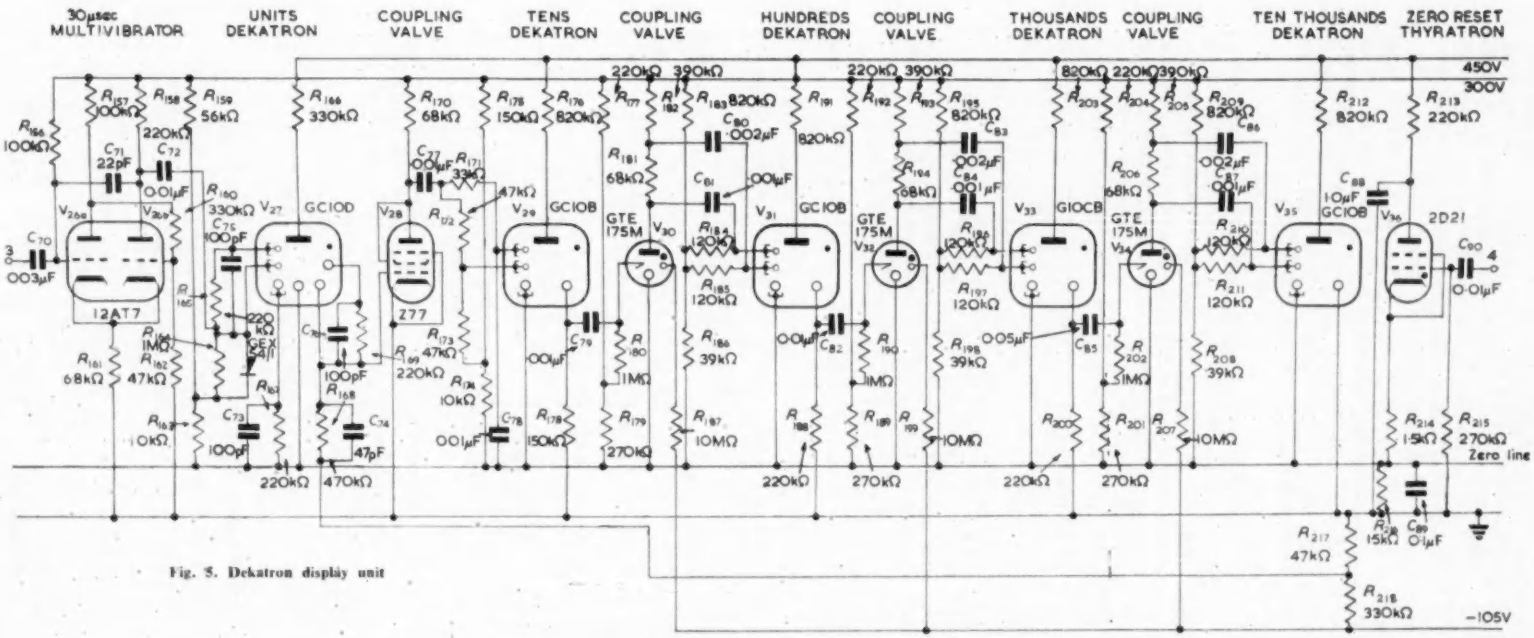



Fig. 5. Dekatron display unit

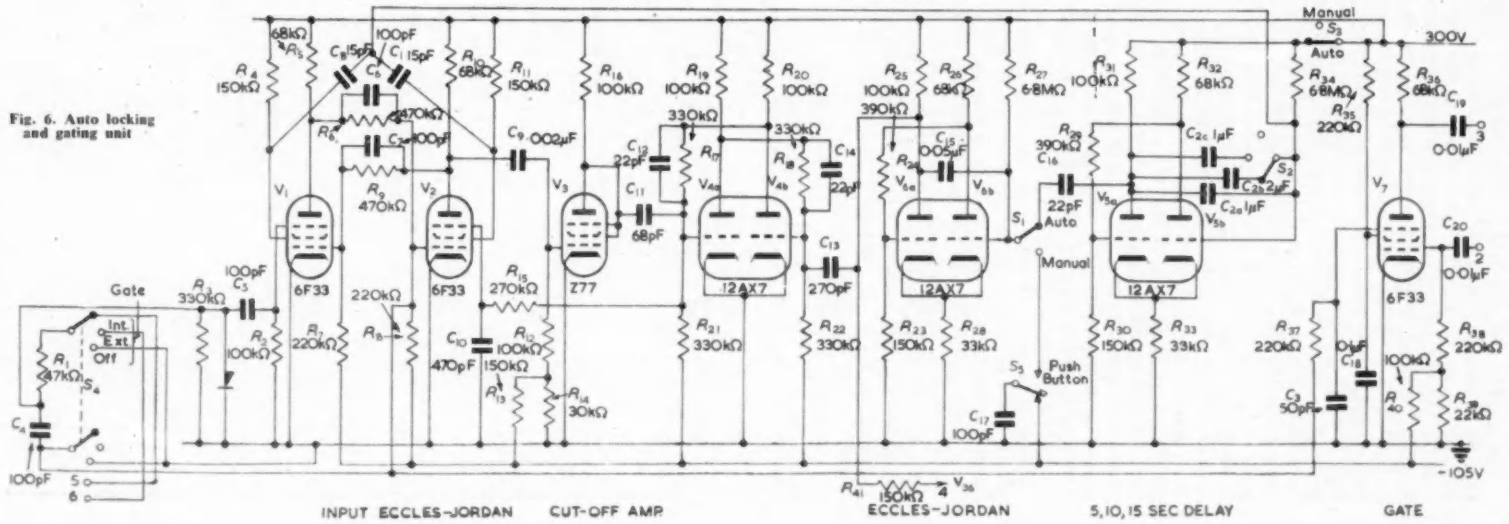



Fig. 6. Auto locking and gating unit

DEKATRON DISPLAY UNIT (Fig. 5)

The display unit has five Dekatron tubes arranged in cascade. When the timing period is 2sec then it is possible to count to 40 000. The limit being set by the maximum speed of the first Dekatron. Negative going pulses from the anode of the gating valve are fed to a 30$\mu$sec one-shot multivibrator. The anode of $V_{26}$ will go negative for the 30$\mu$sec period, this pulse is fed into a GC10D high speed Dekatron. The maximum operating frequency for this tube is stated to be 2 000p/s which represents a periodic time of 50$\mu$sec, therefore the pulse forming multivibrator ($V_{25}$) must produce a pulse width of less than 50$\mu$sec in order to secure reliable running at a maximum speed.

The final cathode of the GC10D ($V_{27}$) is fed to a triode connected Z77 ($V_{28}$) biased to cut-off. The output from $V_{28}$ which consists of 140V negative-going pulses, with a maximum p.r.f .of 2 000, is fed into a GC10B Dekatron ($V_{29}$). This Dekatron is coupled to a third, ($V_{31}$) by a trigger tube $V_{30}$ arranged to operate as a self quenching tube, so that it is extinguished after each input triggering pulse. The last two Dekatrons $V_{33}$ and $V_{35}$ are coupled by GTE175M tubes, $V_{32}$ and $V_{34}$.

In order to return the Dekatrons to the zero position at the end of each counting and display period, it is necessary to make the 'zero line' positive with respect to earth for a short period. The guide electrodes of the Dekatrons are all returned to a common line, the zero line. By making this line positive all these electrodes are made positive with respect to the final cathode and the 'glows' are returned to these cathodes. A tetrode thyratron $V_{36}$ (2D21) is normally biased to cut-off and with the application of a positive pulse to its control grid derived from the auto locking stage (see below), the thyratron conducts, discharging a large capacitor, $C_{40}$, in its anode circuit. A large pulse of current flows through $R_{207}$ raising the zero line some 100V positive for 20msec, thus returning all the Dekatron 'glows' to the zero position.

Provision has been made to use another display unit remote from the main instrument. It consists of a unit identical to the display unit described above, with the exception of the re-setting thyratron. The thyratron ($V_{39}$) situated in the main counter is used to reset both units.

AUTO LOCKING AND GATING UNIT (Fig. 6)

In order that the instrument can count a series of pulses for a given time, some form of gating circuit must be used. After the counting period, in this case either 1 or 2sec, the gate must be closed and remain closed for a sufficient time to enable the display to be read. When the display period is complete the Dekatrons must be returned to the zero position, so that the action can be repeated.

The display time is made a variable period of either 5, 10 or 15sec ($S_2$) to suit different operators and uses to which the instrument may be put. A push-button is also fitted so that instantaneous counts can be made. So that the push-button can be used the delay circuit controlling the display time must be switched out of circuit ($S_3$) thus, after the count has been taken, the display will remain on the display tubes until the push-button is again pressed when the tubes will be returned to zero and automatically

TABLE 1

| VALVE | INITIAL STATES | AFTER 1ST GATING PULSE | AFTER 2ND GATING PULSE | AFTER DELAY PERIOD OF 5, 10 OR 15 SEC | AFTER 200msec DELAY TIME FOR ZEROING DISPLAY |
|---|---|---|---|---|---|
| $V_1$ | ON | OFF Positive pulse through $C_8$ does not operate $V_5$ but ensures it is in its correct state | ON | ON Stages locked by bias on $V_2$ suppressor from $V_{41}$ | ON |
| $V_2$ | OFF Gate shut | ON Gate open | OFF Screen falls, negative pulse through $C_1$ changes $V_5$ to its unstable state | OFF | OFF |
| $V_3$ | OFF | OFF | ON Pulsed | OFF | OFF |
| $V_{41}$ | ON | ON | OFF $V_2$ suppressor biased to cut-off by bias on $V_{4A}$ grid | OFF | ON Removes locking bias from suppressor of $V_2$ |
| $V_{4b}$ | OFF | OFF | ON | ON | OFF |
| $V_{5A}$ | OFF | OFF | ON Delay period | OFF Display period completed | OFF |
| $V_{5b}$ | ON | ON | OFF Ditto | ON Ditto | ON |
| $V_{6A}$ | OFF | OFF | OFF | ON 200msec delay $V_{6A}$ anode instantly rises firing the re-setting thyratron | OFF |
| $V_{6b}$ | ON | ON | ON | OFF Stage initiated by a negative pulse from $V_{5A}$ anode | ON |
| $V_7$ | OFF Controlled by $V_8$ | ON | OFF Gate shut | OFF | OFF |

a new count is taken. The push-button $S_3$ is normally in the lower position as shown (Fig. 6) so that capacitor $C_{17}$ is charged to −105V. When the push-button is pressed $V_{6b}$ grids are driven negative starting the action of the 200msec delay and the circuits associated with it.

The unit consists of two pentodes ($V_1$ and $V_2$) connected as an Eccles-Jordan trigger, the gating pulses from the timing unit initiate the circuit action on the suppressor of $V_1$ and the control grid of $V_2$. $V_1$ and $V_2$ are short suppressor base pentodes type 6F33.

$S_4$ selects the gating pulses, these can be either internal (INT) or external (EXT) or, in the 'OFF' position, the gate is locked open so that random pulses can be counted over an indefinite period of time.

With the switch $S_4$ in the INT position positive pulses are fed through $R_1$ to limit the peak current through the germanium diode shunting $R_2$, this diode removes the negative going pulses produced by the differentiating action of $C_{90}$ and $R_2$.

$V_3$ is biased to cut-off coupling $V_2$ to $V_4$, an Eccles-Jordan trigger is used to lock $V_2$ in the off or non-conducting state.

$V_5$ and $V_7$ are two one-shot multivibrators connected in series. $V_5$ is a variable delay valve providing the delay of 5, 10 or 15sec for the reading time of the display. The actual delay time for the reading depends on the interval between the timing pulses. The multivibrator $V_7$ is actually set for 3, 8 and 13sec so that in the 2sec timing period the actual delay is 5, 10 and 15sec; while in the case of the 1sec timing period it is 4, 9 and 14sec.

$V_6$ provides a 200msec delay during which time the Dekatrons in the display unit are returning to zero. After this 200msec period $V_4$ is switched over and the cut-off bias on the suppressor of $V_2$ is removed and the circuit is returned to a state ready for the next series of pulses to be counted. The complete action of the unit is shown in Table 1.

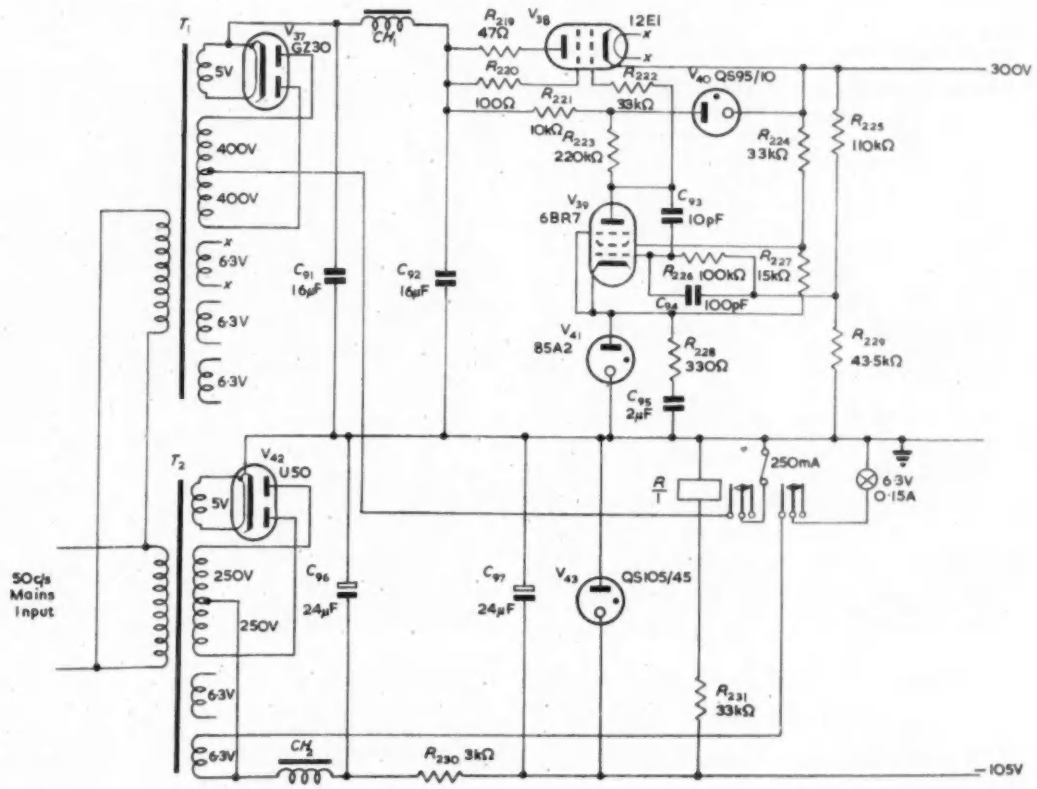
### Pentode Gate

A short suppressor base pentode is used for the gating valve. The operation of the gate is controlled by the suppressor grid which is normally biased to cut off; the bias being produced by the control grid of $V_3$. When $V_1$ and $V_2$ are changed over by the application of the first timing pulse $V_2$ control grid rises to earth potential and the bias is removed from the suppressor of $V_7$. The valve can now operate as a normal amplifier.

Input pulses from either the input limiting amplifiers, or from the scale of ten divider are fed through the blocking capacitor $C_{91}$ to the control grid of $V_7$. The control grid is biased beyond cut-off for two reasons, firstly to prevent a pedestal being formed in the anode circuit as the suppressor bias is removed, and secondly, to suppress spurious pulses from the scale of ten divider. The spurious pulses are produced as a result of suppressing the division ratio from 16 to 10 by the feedback loops. These pulses are accentuated by the differentiating action of $C_{26}$,$R_{53}$. They are, however, of smaller amplitude than the main signal and can be effectively removed by biasing the control grid of $V_7$ beyond cut-off.

When the suppressor bias is removed the grid signals are passed to the anode circuit and hence to the display unit. After the timing period $V_1$ and $V_2$ change over and $V_2$ control grid is biased to cut-off and therefore so is $V_7$ suppressor and the control grid signals are blocked from the display unit.

**Fig. 7. Power supply**



POWER SUPPLY (Fig. 7)

The power supply is in two sections.
(1a) providing 300V at 100mA. (1b) 420 to 450V.
(2) −105V bias supply.

The 300V supply is stabilized against variations in mains supply voltage and has an output impedance of approximately 1Ω, so that no interstage decoupling is required. The 450V supply is unstabilized and is used to supply the anodes of the Dekatrons.

The 105V negative bias supply is stabilized by means of $V_{47}$ (QS105/45). The bias rectifier is a directly heated type $V_{48}$ (U50) so that the bias supply is available before the main h.t. supply to prevent damage to the valves in the main unit. A relay is also incorporated in the supply to guard against either a short-circuit line in the counter or a failure of the bias supply. In either case the relay will not operate and the main h.t. power supply cannot be switched on. An indicator lamp is connected across a pair of relay contacts so that when the bias is on the indicator lamp is lighted.

**Performance and Operation**

The reason for using a two second timing period may seem obscure without reference to Bland and Cooper[1].

In order to measure the speed of rotating machinery a slotted rotor having 30 teeth evenly spaced around the periphery rotates within a stator also having 30 slots cut into its inner edge. The rotor is coupled to the machine shaft; when the machine is rotating the capacitance change from the transducer frequency modulates an oscillator and the resulting frequency change is converted by means of a discriminator, to voltage pulses corresponding to 30 per revolution. Hence by counting over a two second period a direct reading in revolutions per minute is obtained. Although the chance of requiring to measure above 40 000rev/min is remote the extra decade multiplier has been found very useful for general laboratory work.

The instrument was constructed as a number of plug-in units. Each unit is as shown in the theoretical diagrams and fits into a framework inside the enclosing cabinet. The overall size of the cabinet being 10in high, 14in long and 8in deep. Ventilation being by convection only.

**Acknowledgments**

The author wishes to acknowledge the work of Mr. B. J. Cooper on the Timing Panel, and his preliminary work on the Auto Locking Unit. Also Mr. J. Blanchard who made the final assembly of the instrument, introduced several modifications and carried out extensive tests on the tachometer.

The author also wishes to express his thanks to the Brush Electrical Engineering Company Limited for permission to publish this article and to his colleagues for help and constructive criticism during the design and development of the instrument and the preparation of this article.

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# An Internal Defibrillator with Current Measuring Facilities

By B. J. Perry*, B.Sc., Ph.D., A.R.C.S., and R. E. Trotman†, B.Sc., Grad.Inst.P.

THE principle of giving a substantial shock to the exposed heart to stop ventricular fibrillation has been known for some time[1,2]. Originally, short pulses of current of up to 5A r.m.s. were delivered through the heart by direct connexion to the 115V a.c. power supply. Various improvements and additions to the basic method have since been made and are included in this design for the Westminster Hospital Group.

**Basic Circuit**

The diagram of the basic circuit is shown in Fig. 1. Current pulses are derived from the secondary of the isolating transformer $T$ and are controlled in length by a foot, hand or timer operated contact $S$. Current control is by the variable resistor $R_1$, there being a small value fixed resistor $R_2$ in the secondary circuit at all times. The secondary voltage of the transformer is 120V r.m.s. and the transformer is rated to give an output of one pulse of 0·2sec duration every second to a maximum r.m.s. value of 5A.

As an alternative to providing a variable resistor $R_1$ to vary the average current during a pulse, the primary of the isolating transformer can be fed from a variac or similar device or the secondary of the transformer can be provided with a series of voltage tappings and the pulse current is varied by tap switching[3].

**Current Measurement**

The average r.m.s. current passed during a pulse can be measured on a conventional moving-iron or moving-coil ammeter if the length of pulse is sufficient[1,2]. The usual pulse length is, however, of the order of 0·2sec and an ammeter is unsatisfactory. A simple valve memory circuit has, therefore, been devised which measures the peak value of current during a pulse and is calibrated in terms of the r.m.s. value of current passed during the pulse.

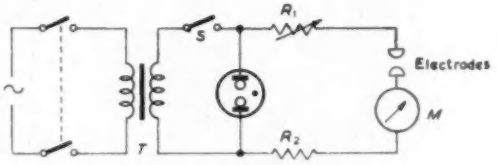


Fig. 1. The basic circuit

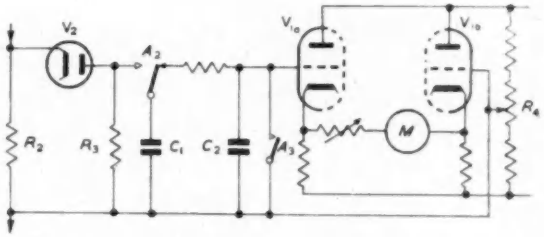


Fig. 2. The principle of the current measuring memory circuit

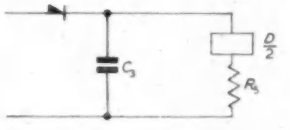


Fig. 3. The timing device

During a pulse the capacitor $C_1$ (Fig. 2) is charged through the diode $V_2$ and the contacts $A_2$ from the voltage developed across $R_2$. Contact $A_3$ shorts $C_2$ ensuring that no charge remains on it. At the end of a pulse contacts $A_2$ and

* *Formerly Westminster Hospital, now St. George's Hospital.*
† *Physics Department, Westminster Hospital.*

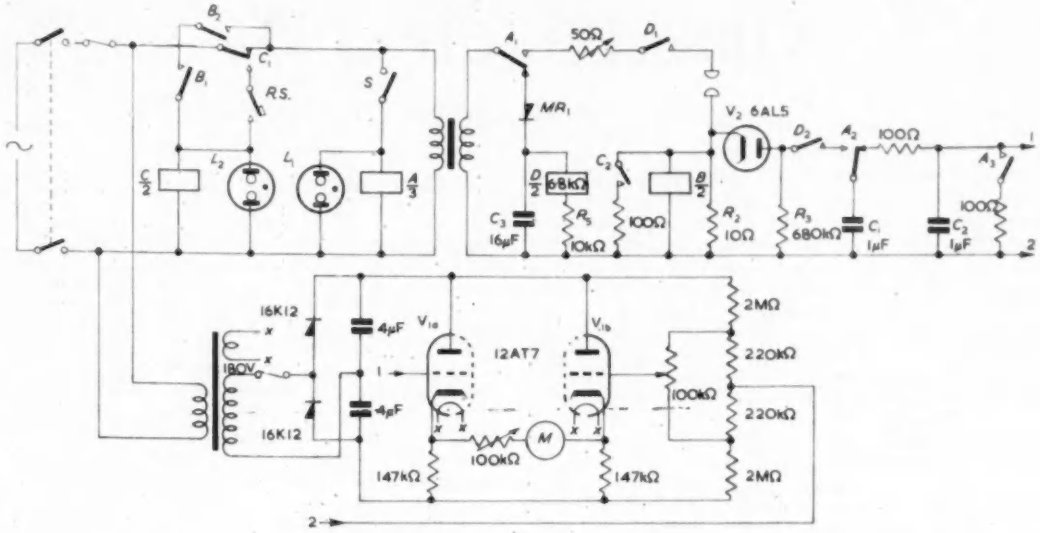


Fig. 4. The complete circuit diagram of the instrument

$A_3$ are released thus allowing the charge on $C_1$ to be shared with $C_2$. The resultant voltage across $C_1$ and $C_2$ is measured by the valve-voltmeter formed by $V_{1a}$ and $V_{1b}$ and meter $M$. The meter $M$ (1mA f.s.d.) thus gives a measure of the peak current of the pulse, the meter reading being adjusted to give a full scale deflexion for a current of 5A r.m.s. through $R_2$. $R_3$ provides a diode load and also allows some of the residual charge on $C_1$ to leak away during a pulse if the peak current of the pulse is much lower than the peak current of the previous one.

The meter gives an indication of pulse current immediately after the pulse has occurred and will hold this reading for some time due to the large capacitance of $C_1$ and $C_2$ (now in parallel) and the low value of grid current of $V_{1a}$. About 4 per cent of the full scale reading is lost in 10min. The zero stability is good due chiefly to its balanced arrangement and the high level of output voltage corresponding to full scale deflexion. If zero adjustment is necessary it is achieved by altering the setting of potentiometer $R_4$.

Fig. 5. The internal defibrillator and accessories

## Timing of Pulse

The optimum time of pulse required is 0·2sec and it is almost impossible to judge that order of time accurately when using a hand or foot switch. It is therefore desirable to have some sort of timing device. The time of application may be controlled as here by an $RC$ circuit (Fig. 3), or by a slugged relay[4] or a clock controlled switch, depending on the length of time required.

## The Complete Circuit

The complete circuit of the defibrillator is shown in (Fig. 4). The foot or hand switch $S$ operates relay $A$. Contact $A_1$ completes the secondary circuit and the current passes to the patient. Contacts $A_2$ and $A_3$ operate as before. The length of pulse is defined by relay $D$. This is normally on due to the connexion via the back contact of changeover contacts $A_1$. On pressing switch $S$ the charge on capacitor $C_3$ begins to decay and the time-constant $C_3$ ($R_3 + D$) is arranged so that relay $D$ remains on for 200msec after relay $A$ operates. When relay $D$ releases, contact $D_1$ opens the transformer secondary circuit and contact $D_2$ prevents $C_1$ discharging through $R_3$ during the time that relay $D$ is released, but $A_2$ not yet opened.

Relay $B$ is an overload relay adjusted to operate at a pulse current of 5A. The operation of this relay brings on the locking relay $C$. The contacts of relays $B$ and $C$ are arranged so that relay $C$ is fully held on before $B$ is released and the primary circuit of the transformer opened. This arrangement ensures that there is no contact race and is a precaution against relay chatter and premature and uncertain operation. Reset switch $RS$ prepares the circuit for immediate use.

The neon indicator $L_1$ lights whenever a pulse is passed and $L_2$ indicates an overload.

The whole apparatus is shown in Fig. 5 including the large curved electrodes and both a hand and foot switch. These accessories are attached to the instrument by push lock plugs and sockets.

**Acknowledgments**

Acknowledgment must be made to Dr. C. W. Wilson in whose department this instrument was developed and to Mr. David McNish for his constructional help. The apparatus is covered by British Patent No. 16505.

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# VIBRATO CIRCUITS
## for Electrical Musical Instruments

By Alan Douglas, M.I.R.E., M.Amer.I.E.E.

*The judicious use of vibrato enhances the value of many musical sounds. In this article it is shown how electrical or mechanical devices attempt to provide some, at least, of the characteristics of this embellishment.*

A GOOD deal of misconception exists as to what is meant by vibrato or tremolo. There is further confusion because the stop causing this effect is called a tremulant on a pipe organ. From a strictly musical point of view, vibrato means a form of frequency modulation while tremolo is not a modulation at all, but a rapid reiteration of a note without any change in pitch and without specific reference to time. This is often accomplished on the violin, for example, by rapid up and down bowing.

The tremulant on an organ is a corruption of the word 'tremblant', introduced by the French who were the first to apply a mechanism to cause a regular cyclic change in wind pressure. In present day practice, the apparatus produces both frequency and intensity changes; it is a true vibrato.

Therefore, although some writers refer to tremolo as an intensity modulating system for an electronic sound source, it does not produce a true musical tremolo which may be—and often is—a series of quite discontinuous notes.

It is evident that tone sources, the frequency of which is not readily varied, such as vibrating reeds and constant-speed rotating generators, may have to put up with a form of tremolo if a waver in the sound is required. This is a thoroughly bad thing; it never occurs in natural sounds and while at first it may seem to soften the effect of a sustained note, the invariable rate of repetition and the constant depth of switching soon takes control of the sound which becomes domineering and aggressive because of the monotony.

We can disregard this type of level modulation and concentrate on vibrato. This has its origin in emotional or biological tremors and is a musical asset of the greatest value when properly applied. Indeed no orchestral or vocal music can exist without some contribution from vibrato. Too much space would be occupied if the whole process of the pschycological evolution of vibrato was analysed[1], but the following should be noted as essential attributes—

(1) For preference, both frequency and intensity should be altered.

(2) The rate of vibrato is roughly proportional to the frequency of the noted played.

(3) The intensity should be related to the loudness of the note.

(4) Powerful sound sources do not lend themselves to the application of vibrato.

The foregoing are equally applicable to the singing voice, although this does not concern us. The full beauty of vibrato is exemplified by a solo violincello, the greatest abuse by the cinema organ played 'all out' with tremulants

Related to vibrato but quite separate is the choir effect due to many sounds of constantly changing phase heard simultaneously; and the voix celestes and unda maris, a strictly pipe organ effect employing two complete ranks of pipes having each pair (sounding the same note) tuned to give a beat of one or two per second with each other. These elusive and romantic effects cannot be synthesized electrically, or only at very great expense, although they are to some extent present in electronic organs having quite independent oscillators for each note; such instruments have therefore a greater richness of tone quality than organs using frequency division or mechanically linked generators.

We have, then, to make the best of frequency or phase modulation in one form or another. Great though the value of vibrato is to orchestral or vocal music, it is of even more value with electronic tone generators. These have (except for certain very advanced monophonic instruments) a steady waveform and a steady harmonic content for any one note at any instant. Vibrato smooths the harmonics and modulates the waveform, thus greatly modifying the tonal presentation. Against this must be offset the fact that an electrical vibrato is not progressively and continually adjustable, except in certain instances[2,3]; therefore caution is required in applying this effect, but this would be expected from a musical standpoint.

It is conceded that a modulation rate between 5 and 8c/s is most agreeable, and that vibrato should not be applied to notes much below 130c/s. This is because of the dissonance associated with low-frequency beats[4].

There is no general agreement over the depth of vibrato; since with a tremolo there is no deviation from pitch, this may be very intense; but with the frequency excursions due to vibrato, too great a swing is unpleasant. Occasionally this may be noticed in vocal music. It would appear that about 10 cents or one tenth of a semitone is a reasonable pitch deviation, and if this is not proportional to the accompanying changes in level, the latter can be quite considerable; but a true frequency modulation can be effective if there is no change in level at all. It all depends on the application.

Taking the simplest case first, most forms of multivibrator are susceptible to frequency change if the h.t. line voltage is varied. Fig. 1(a) shows such a circuit, suitable for a monophonic instrument. If the anode supply to one half of $V_2$ is fed through the potential divider formed by $R_1$ and $R_2$ in the anode circuit of a low-frequency oscillator, the supply to $R_3$ undergoes a cyclic variation and vibrato is produced at the output $C_1$. The depth of modulation is adjusted by varying the ratio of $R_1$ to $R_2$, but in such a circuit $R_2$ forms part of the frequency determining circuit of $V_2$ and hence cannot be altered to change the degree of vibrato. If this condition is required, the vibrato oscillator must be isolated from the tone generator by a valve as is Fig. 1(b). In this instance the cathode current is modulated but the vibrato generator may be switched to several rates or degrees of modulation without affecting the tuning of the tone generator.

Oscillators used to generate the low-frequency vibrato voltage should have a symmetrical and smooth waveform. Phase shift circuits are very suitable. It will be appreciated that square and other steeply rising waveforms may themselves modify the waveform from the tone generator. A sine wave is desirable. One such circuit[5] which is particularly good is shown in Fig. 1(c). This has the advantage

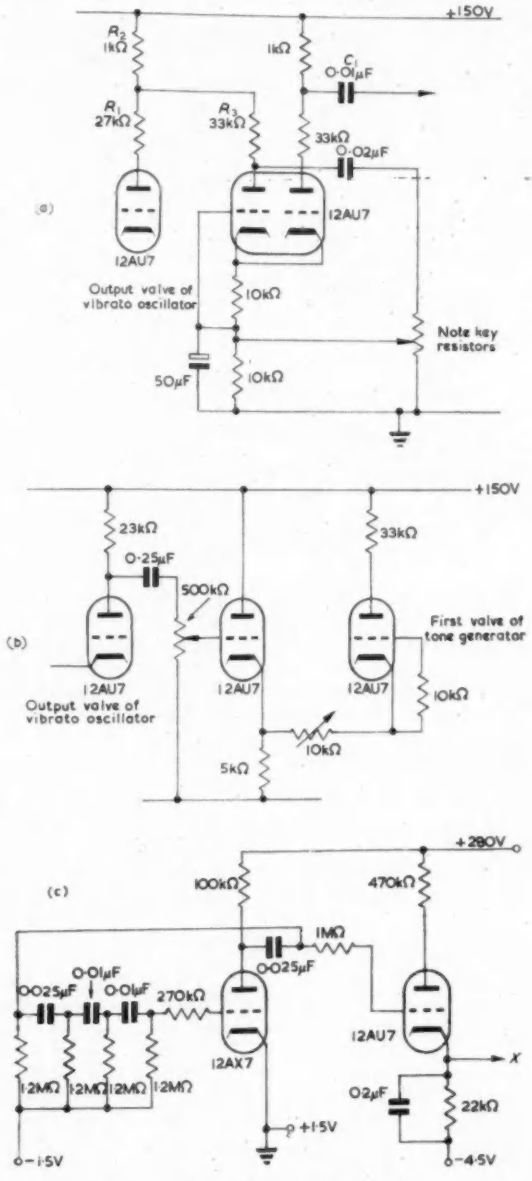


**Fig. 1. (a) Tone multivibrator with vibrato (b) Vibrato circuit with buffer valve (c) Phase shift vibrato oscillator**

that d.c. modulation can be carried out in the cathode circuit of $V_2$, so that grid bias control is available for other kinds of oscillator; for example that of Fig. 2.

This type of oscillator may be adjusted to be little influenced by normal changes in h.t. line voltage, so that grid modulation is the most effective method of applying vibrato. If the grid resistors are connected to the switch at the point marked *X* in Fig. 1(c), vibrato may readily be started or stopped without any change in the steady frequency.

Such a system can be used in a musical instrument employing frequency dividers, since the dividers are locked too tightly to be directly influenced by vibrato circuits. It does, however, lead to the condition common to most electrical musical instruments that the one vibrato frequency is applied over the whole compass. This is not compatible with the effect as employed by orchestral players, where the rate of vibrato varies with the frequency. As is well known, the multiple phase changes brought about by superimposing the many vibratos leads to an extraordinary richness of tone. It is evident that one cannot economically have an infinite number of such phase variations, although it is quite feasible to provide vibrato generators for each

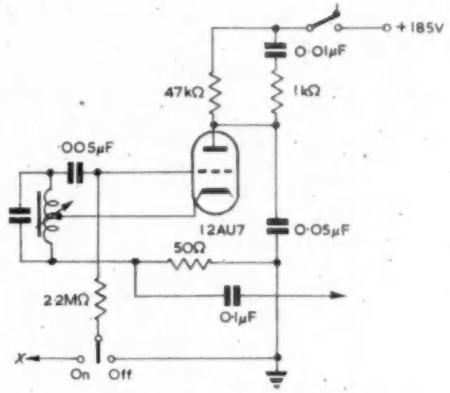


**Fig. 2. LC tone oscillator with vibrato switch**

octave from tenor C upwards; each oscillating at a slightly different frequency.

A considerable step forward was taken by Hanert in designing the line vibrato circuit[6] of Fig. 3. While the delay from the static line does vary linearly with frequency, it is further modulated by a scanning element in the form of a variable capacitor having 16 fixed sections connected to selected parts of the line, with a single set of rotating vanes operating at 412 rev/min. The signal is retarded in phase by each line section and each group of sections is modulated by the rotary scanner so that the whole line is scanned in about 1/14sec. This rate of change causes about 1·5 per cent decrease in frequency and this is constantly low to that extent so long as the capacitor is rotating at a uniform speed. Switching arrangements permit of the whole, half and one third of the line being scanned at will, thus altering the depth of vibrato.

While the effect from this current is much more realistic than that from fixed frequency vibratos, the most interesting result arises from mixing some of the signal through the line with some of the signal before it has been applied to the delay line. An extremely complex system of small amplitude beats is thus set up, and some approximation to a true chorus is obtained; since no one can tell in advance the phase relationships of the generators at the instant of keying the signal. In the present state of the art, this arrangement is less tiring and much less cyclically evident than any other electrical vibrato system for polyphonic instruments.

As stated above, some tone systems cannot be frequency modulated owing to their inherently high stability and in

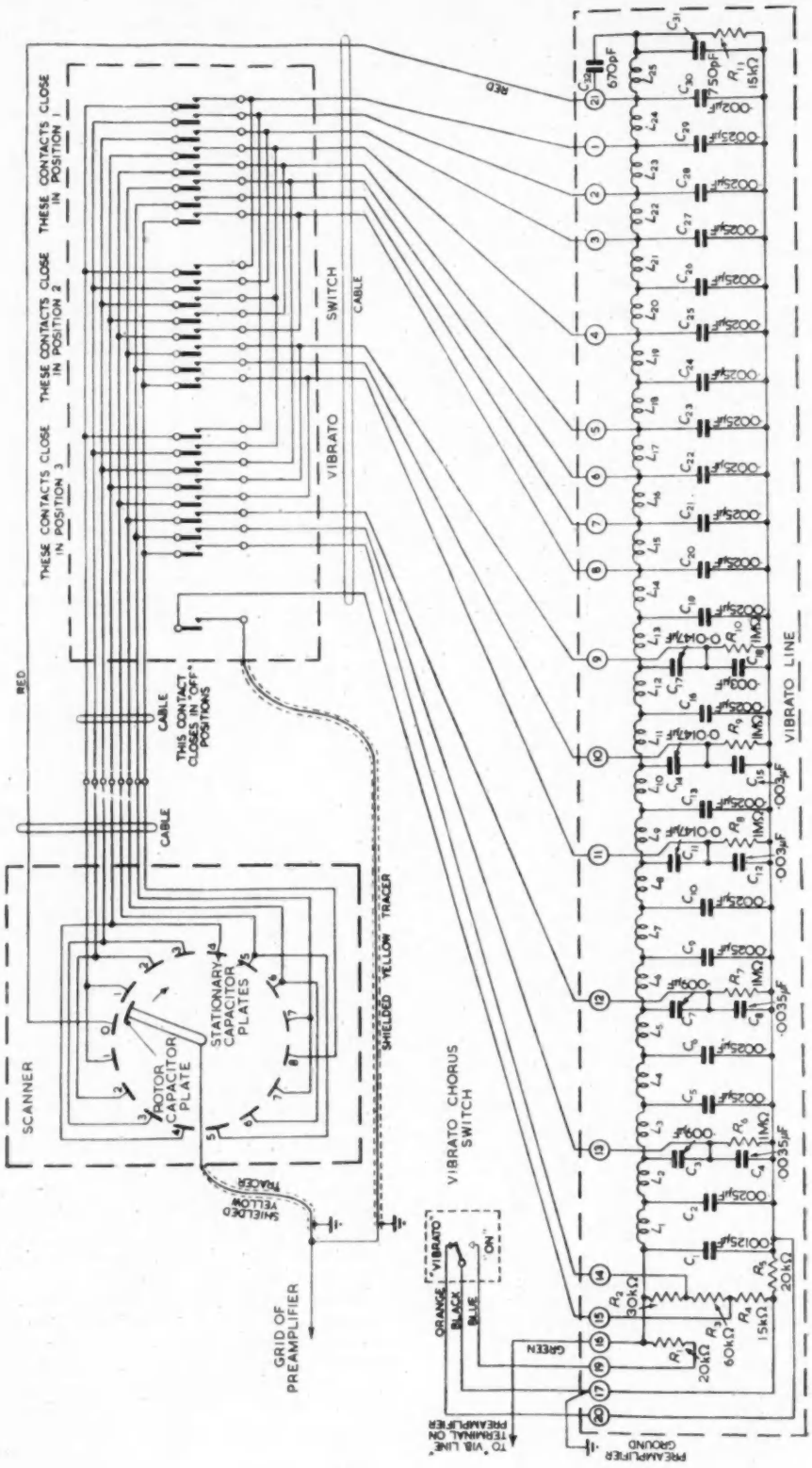


Fig. 3. Delay line vibrato circuit

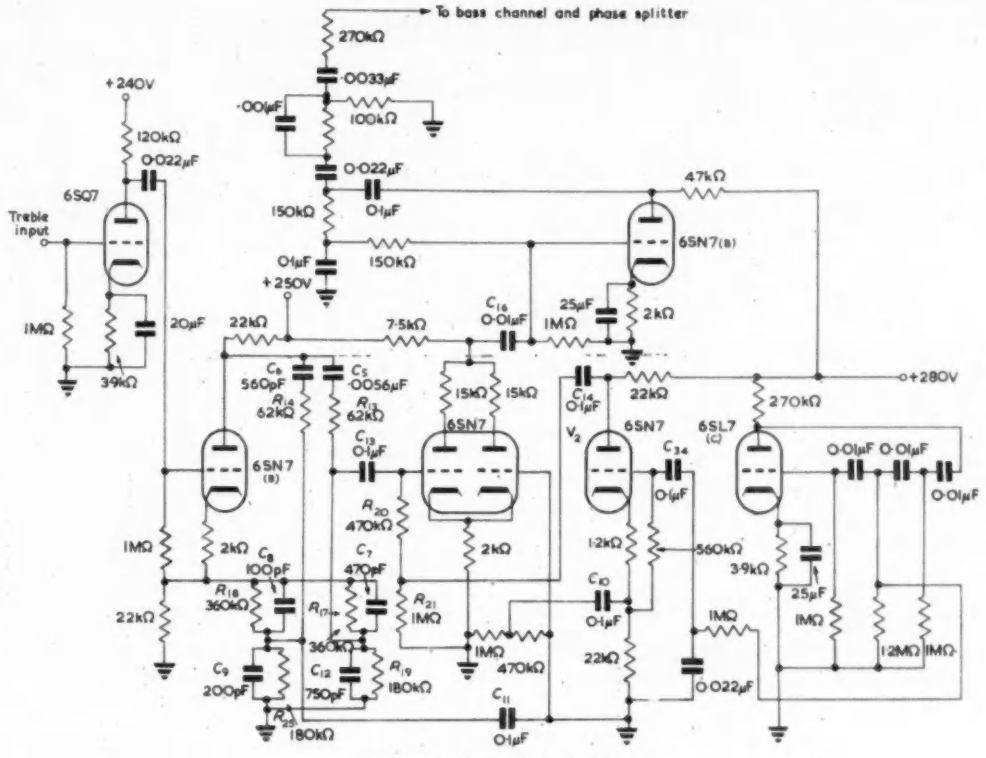


Fig. 4. Wurlitzer vibrato circuit

such cases a circuit which can be applied after the generator may be very useful. There are now many circuits for producing a phase shift proportional to frequency, but the arrangement used in the later Wurlitzer instruments is interesting. Free reeds do not appreciably change their pitch with a change in wind pressure, this being taken advantage of in the 'expression' stop in harmoniums and the Mustel reed organ. This stop disconnects the wind reservoirs and puts the reed chests in direct communication with the bellows. Thus by 'expressive' pedalling, the volume can be regulated from a whisper to full, without change in pitch; often to be heard from the Mustel reed organ in the Palm Court Orchestra broadcasts.

In Fig. 4, which shows the Wurlitzer circuit, the signal is first divided so that notes below 130c/s are not modulated. With vibrato, the treble signal passes through the input valve to half of a 6SN7 connected as a phase invertor. Again, the out of phase signals from the anode and cathode divide between the networks $C_7 R_{21} C_9 R_{19}$; and $C_7 R_{17} C_9 R_{18}$. These four circuits are connected by $C_9 R_{22} C_{12} R_{19}$ to form two output circuits. The phase-angle between each of these networks and the input voltage increases almost linearly with frequency between 500c/s and 15kc/s. The outputs of these networks come through $C_{13} C_{11}$ to the grid of the 6SN7 mixer valve, 90° apart.

The phase shift oscillator using half a 6SL7 (c) supplies $V_2$ through $C_{34}$. This is another phase invertor, the outputs of which are connected through $C_{10} R_{23} C_{14} R_{20}$ to the grids of the 6SN7 mixer. The low-frequency signal thus controls the conductivity of the two sections of this 6SN7. When section (1) is conducting, section (2) is nearly cut off. The output signals are thus alternately delayed by about 90°. This shifting to and fro between the two signals produces an apparent frequency change to the ear. The output from the mixer is then fed to one half of the 6SN7 (B) feedback filter stage which cuts off sharply below 130c/s. This is to prevent the phase-shift oscillator frequency from appearing as part of the musical signal. The modulated signal then joins the bass amplifier and so proceeds to the output stage.

It has often been suggested that a mechanical modulator be used at the actual loudspeakers. Such arrangements can be very effective if the mechanism can be so arranged that it does not interfere with the free sound field when not in use. Any such scheme must be based on the Doppler effect, the frequency $f$ at the point of observation being

$$= \frac{V}{V - V_s} \cdot f_s$$

where $V$ = velocity of sound in the medium

$V_s$ = velocity of the source

$f_s$ = frequency of the source.

The sound therefore rises in pitch if a rotating paddle is placed in front of the loudspeaker cone, and as this turns in the direction of the observer; equally the sound falls in pitch as the paddle turns towards the cone. Incidentally this is an instance where the frequency and the pitch are not numerically equal.

The Allen organ company used a loudspeaker rotating on an elliptical axis at the top of a long wooden tube, like a stopped organ pipe, for a long time. In their more recent installations, medium and high frequency units are rotated on a plane baffle[2]. It is clear that very fine control of the effect is possible from an infinitely variable speed motor. The method is very successful, if cumbersome.

A scheme dating back thirty years is shown in Fig. 5. The signal is applied to the 'armature' and removed from

the field windings. It is rather difficult to ensure that the degree of magnetic coupling is exactly the same each time the device stops, for unless this is so, the level will change.

A quite new approach to the problem of adding some chorus effect to a frequency divider organ is due to the

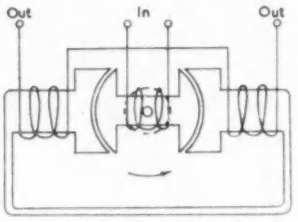


Fig. 5. Early rotary vibrato

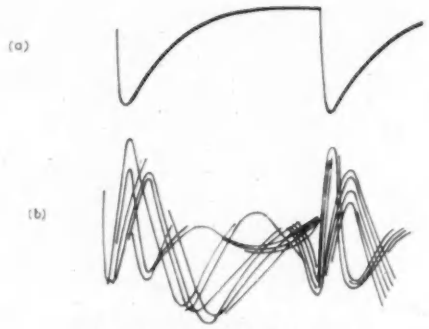


Fig. 6. Waveforms of Baldwin system

Baldwin company. The signal is fed into a circuit which produces a three-phase signal from the input. This passes through a single sideband suppressed carrier modulator unit. The modulator contains an oscillator, which in effect determines the amount and the direction in which the original signal should be altered in frequency. Thus not only is frequency modulation applied but also, some degree of amplitude variation.

As an example, a 375c/s note would be reduced by 1c/s, a 750c/s note increased by 2c/s; a 1 500c/s note reduced by 4c/s; and a 3 000c/s note increased by 8c/s. This continual phase and amplitude shifting over the compass (at least, from 200 to 4 000c/s) results in a complex changing wave pattern as in Fig. 6, which shows a string tone waveform as generated and when passed through the modulator unit. Such circuits add considerable richness to the tone quality.

Monophonic or melodic instruments may be fitted with more exact forms of vibrato control. In the Trautonium, for example, a liquid resistor in the form of a long tube

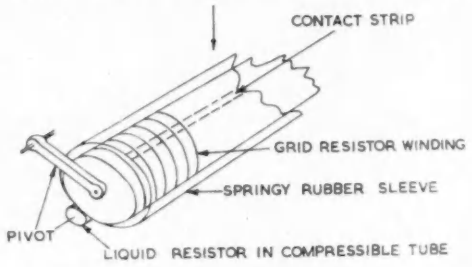


Fig. 7. Trautonium variable touch device

can be depressed by the 'manuals', to form infinite gradations of volume and so, a vibrato. This idea holds great possibilities (see Fig. 7). Playing keys have been devised which can move longitudinally as well as up and down, such sliding action being used to control feedback capacitors or inductors to regulate a vibrato voltage. The monophonic instrument would appear to offer many opportunities for ingenuity in design here; but so far as polyphonic keyboard instruments or those which must conform to strictly conventional design are concerned, the application of a true vibrato in the orchestral or temperamental sense remains unsolved.

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## High Altitude Rockets

A Skylark high altitude research rocket was fired in darkness at the Woomera rocket range recently. It reached a height of 83 miles. It was the fourth of six proving rockets scheduled to be fired before the beginning of a joint programme of upper atmosphere research by the Royal Society and the Royal Aircraft Establishment.

The first three firings having shown the performance of the rocket vehicle and its Raven solid propellant motor to be very satisfactory, attention has been turned to trials of rocket-borne equipment and instrumentation, as well as special ground equipment. Skylark No. 4 carried, in addition to routine instrumentation, the equipment for four separate high altitude measurements, each under test but complete and capable of making the required measurements. The four equipments were:—

*Grenades.* Eighteen grenades each carrying about 1lb of explosive composition, to be ejected from the rocket at three second intervals above 100 000ft altitude. On the ground there were microphones to record the time of arrival of the sound waves, ballistic cameras to record the positions in space of the flashes and a detector to record the instant of each flash. The experiment which is being made by University College, London, aims at measuring atmospheric temperatures and high altitude wind velocities. In this flight three different types of grenade were being tested, and the microphones, cameras and flash detectors were in use together for the first time.

*Window Cartridges.* Fourteen cartridges of window (well known in its wartime role as a confuser of radar) to be released explosively in two clouds at different heights above 100 000ft; these clouds were then to be followed by tracking radars. The experiment, devised by Imperial College, London, is designed to measure winds at altitudes up to 50 miles.

*Dielectric Experiment.* A section of the rocket nose was insulated from the remainder of the body to form a capacitor of fixed value. This capacitor was made part of a 5Mc/s oscillatory circuit which can detect the presence of electrons in the ionosphere the results being telemetered to the ground. This very simple but ingenious method of measuring ionospheric electron densities, which has been devised by the University of Birmingham, will be more effective in later rockets which will penetrate further into the ionosphere.

*Pressure Gauges.* Three Pirani pressure gauges were carried in the rocket cone, one measuring ram pressure in the very tip of the nose, the other two measuring cone wall pressures. These measurements, being made by the Royal Aircraft Establishment, enable the undisturbed ambient pressure at various altitudes to be determined.

Besides these main items of equipment, Skylark No. 4 carried timing gear and switches, telemetry sender, power supplies, Doppler transponder and microwave beacon, the last two items being used for tracking purposes to give velocity and position. The flight was made at night for the convenience of the grenade experiment. The rocket nose, which carried a payload of 130lb, was exhibited publicly at the Symposium on High Altitude Rockets and Satellites at Cranfield in June of last year.

# A Feedback Electrometer Amplifier

By D. Allenden*, A.M.I.E.E.

*The drift problem in direct-coupled electrometers is discussed briefly, and a design for a direct-coupled feedback electrometer amplifier which uses its inherent feedback loop gain to stabilize the electrometer valve filament supply is presented and described in detail. It is concluded that direct-coupled amplifiers with zero stabilities of the order of a few millivolts per hour can be realized using economical circuits and simple power supplies.*

ONE of the major objections to the use of direct-coupled amplifiers is the existence of zero-level drift due to changes of effective heater-cathode potential. This problem is particularly acute in direct-coupled electrometers since the electrometer valve usually gives little, if any, gain, and hence drift in the second stage of the amplifier is as significant as in the first. The magnitude of the drift is normally of the order of 10mV per 1 per cent change in heater voltage[1], resulting in a probable total zero instability of 20 per cent of f.s.d. in the typical case of a current measuring amplifier in which 1V is developed across the input resistor. With a low gain input stage, variations of h.t. supply voltage are more significant than usual, but there

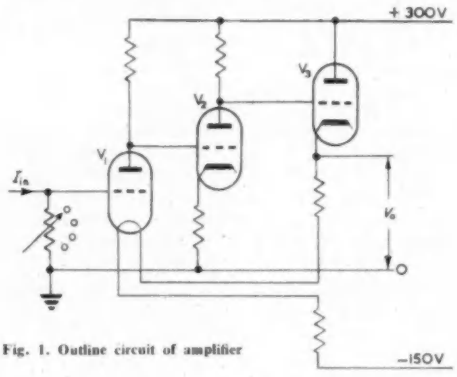



Fig. 1. Outline circuit of amplifier

is no real problem here, since h.t. voltage stabilizers of adequate performance present no design problems. The drift figure quoted is commonly reduced by a factor of 5 or so by the use of balanced stages: better results can be obtained by effective stabilization of the heater supply, a practice which has been little resorted to in view of the inconvenient voltage and current level at which the average valve heater operates. In the electrometer field, the only alternative amplifier is the vibrating-capacitor electrometer[2], which may have zero drifts less than 100$\mu$V per day: the cost of this instrument, however, tends to preclude its use except in cases where this order of stability is essential.

There exists therefore a demand, particularly in the field of vacuum physics, for an electrometer with zero stability of the order of a few millivolts with greater linearity and calibration stability than can be realized with simple non-degenerative balanced circuits. The recent development of pentode electrometer valves such as the CV2348 (ME1403), which feature both significant gain and very low filament consumption (8·2mA at 1·4V), have made such electrometers not only practicable but realizable with considerable economy of valves and components. This article gives details of a design of which some half-dozen examples have been constructed and which have given trouble-free service for over a year.

* *Associated Electrical Industries Ltd.*

## General Circuit Arrangement

### Outline of Operation

An outline circuit is given in Fig. 1. The current to be measured is passed through a suitable high-value resistor and the resultant voltage drop amplified in a 'ring-of-three' feedback amplifier. The electrometer valve, $V_1$, operates with an anode voltage of 15V and is directly coupled to the second stage which is in turn directly coupled to the cathode-follower, $V_3$. $V_3$ anode current is chosen to be 8·2mA, so that feedback and filament supply to $V_1$ can be effected by including $V_1$ filament in $V_3$ cathode resistor chain. A negative supply line is necessary to permit correct

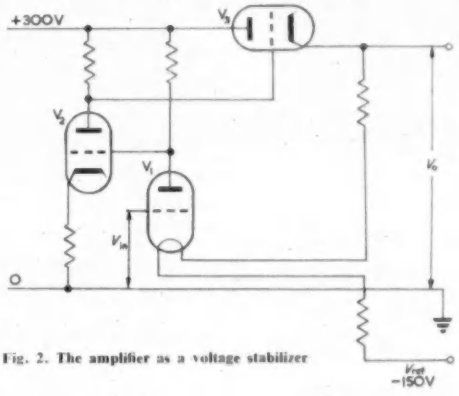



Fig. 2. The amplifier as a voltage stabilizer

d.c. voltage levels to be established without sacrifice of loop gain.

### Zero Stability Considerations

The factors which influence the zero stability of the circuit are perhaps better understood by reference to the re-drawn circuit of Fig. 2. It is here seen that in the absence of input voltage the system is a degenerative voltage stabilizer in which the negative supply line is the reference potential relative to which the voltage level of $V_3$ cathode is stabilized, and that $V_1$ filament is supplied from this stable source. A signal applied to $V_1$ grid changes the effective reference voltage of the system, so changing the output voltage. The fractional variation of $V_1$ filament current in the absence of input is, at most, about double the fractional variation of the reference line. The fact that this is a larger variation than would result from feeding the filament from the reference line is not of great consequence, since the stability easily realizable is such that the residual drift is due to causes other than filament voltage changes. Furthermore, a direct filament feed would complicate the feedback arrangements and inevitably reduce the loop gain, although a successful application of this method has been described[3]. The filament current obviously changes when a signal is applied, but changes of this nature are systematic, and their effects are automatically included in the calibration; it is hence necessary only to ensure

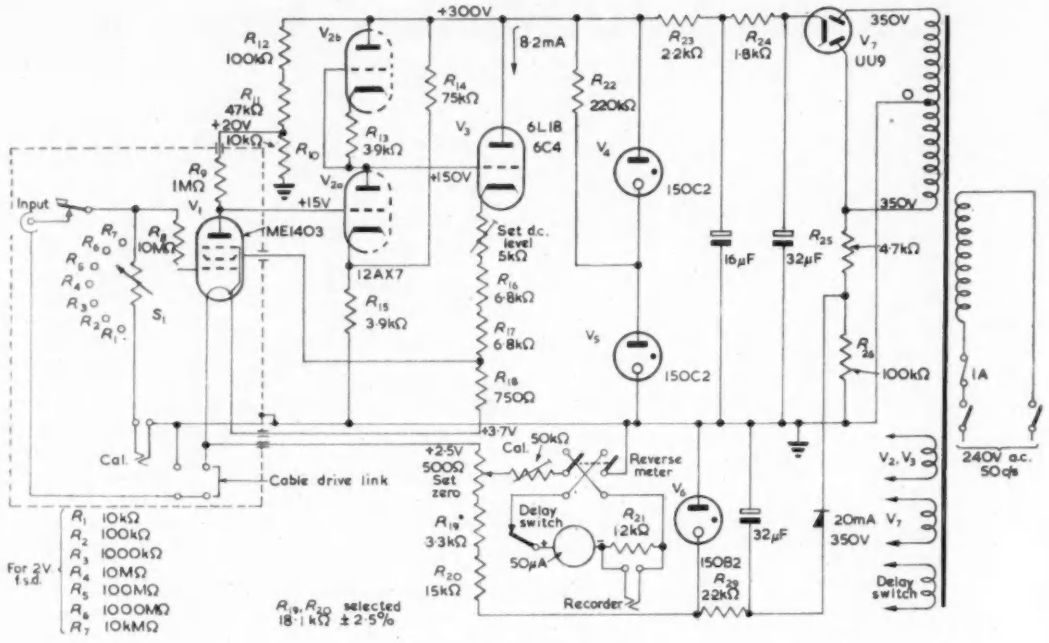



**Fig. 3. Electrometer amplifier**

that the allowable variation (±1mA) in nominal filament current is not exceeded. Adverse effects on valve life are thereby avoided.

### Detailed Circuit Description

Fig. 3 gives a complete circuit of an amplifier with a full-scale voltage sensitivity of 2V, for measurement of ion or electron currents down to $2 \times 10^{-12}$A (f.s.d. $2 \times 10^{-10}$A), though this does not represent the maximum sensitivity realizable with this design.

#### Electrometer Stage

$V_1$ operates with an anode voltage of 15V and a 1MΩ load resistor, and under these conditions a gain of at least 10 can be realized. Grid bias for $V_1$ is obtained by arranging that its filament sits some 2·5V positive of earth, the system being self-regulating. The screen-grid of $V_1$, which for true pentode operation at zero frequency should have its potential fixed relative to that of the cathode, is fed from a tapping 6·25V above the filament. There is a small though insignificant amount of positive feedback inherent in this method of supply. $V_1$ anode supply is taken from a potential divider to limit $V_1$ anode excursion should the valve be cut off.

#### Intermediate Stage

With a gain of 10 in $V_1$, heater-cathode drifts in $V_2$ can be just significant if no stabilization or compensation is applied to this stage. $V_2$ therefore employs series-valve compensation[4], a method which is one of the more successful of the available techniques. A 12AX7 twin triode is employed, one-half of the valve acting as anode load for the other. The two triodes have large degenerative cathode resistors of equal values, so that the stage consists essentially of an equivalent generator of output impedance ($r_a + (1 + \mu)R_k$) feeding a load of the same value; a gain of $\mu/2$ ($\simeq 50$) is thus realized in spite of the presence of $R_{15}$, which is in any case necessary to maintain the correct d.c. level at $V_{2a}$ cathode. If heater-cathode variations are the same in both triodes, there is complete cancellation. In practice, this is unlikely to be the case, though complete cancellation can be realized by variation of $V_{2b}$ cathode resistor; with such adjustment, drifts as low as 150μV/h have been realized. Even without this refinement, the series compensation technique is inherently better than most others; this is probably because the two triodes must operate at the same anode current and voltage, and their dynamic impedances are largely determined by the relatively stable $(1 + \mu)R_k$ term.

#### Output

$V_3$, the output cathode-follower, is designed to operate at an anode current equal to the filament current required in $V_1$, and its cathode load resistor is returned to a 150V negative line. The d.c. operating level of $V_3$ cathode is determined by the effective β-ratio of the equivalent stabilized supply, and it is desirable to provide pre-set adjustment of this level. Any such adjustment is better located in the upper end of the cathode chain, since in this position it does not alter $V_1$ filament current; this is determined by the resistance of the lower part of the chain, and the components here ($R_{19}$, $R_{20}$) should have suitably small tolerances.

The output meter is connected between the 'earthy' point of $V_3$ cathode chain and earth. Since the β of the feedback loop is affected by the meter, and also since meter current is drawn through $V_1$ filament, a high-sensitivity (50μA or 100μA) movement is desirable. In the circuit shown, provisions for meter reversal and insertion of a high-sensitivity recorder or external meter are included. The zero stability with the meter connected at this point is exceptionally good, since, for all variations other than those due to an input signal, the meter feed point is only a volt or so removed from the virtual earth of the stabilizer.

#### Input Circuit

Input arrangements are conventional. A selector switch $S_1$, which must naturally be of a high insulation type, selects

the desired measuring resistor. The earthy ends of the resistors are returned to the common line via a closed-circuit jack which enables calibration or backing off-signals to be introduced on any range. The whole input stage is enclosed in a light-tight screening box. The input cable capacitance can be driven from $V_1$ cathode, giving a significant improvement in bandwidth. The cable could be overdriven by taking the drive from a tapping on $V_3$ cathode chain somewhat above the filament, and this would allow the effect of the residual input capacitance across the resistor (not normally subject to feedback) to be reduced. Instability can result if excessive drive is applied, however, and its adjustment is likely to be critical. The residual capacitance can also be reduced to some extent by a guard-ring driven from $V_1$ cathode, and more elegant multiple guard-ring systems of greater efficacy have been described[5,6].

### Power Supply

The stability of the negative supply line is obviously of importance, since $V_1$ filament current and, to a large extent,

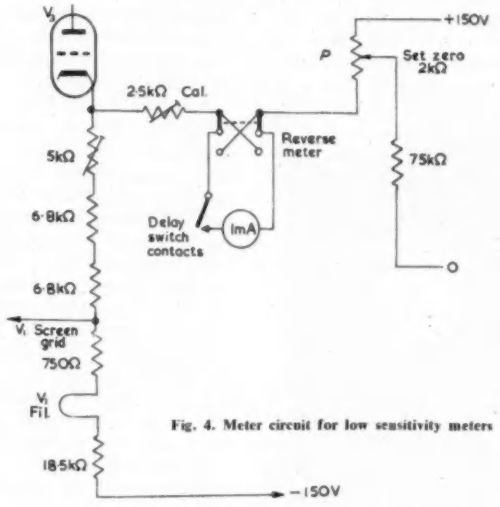



**Fig. 4. Meter circuit for low sensitivity meters**

the zero stability of the whole system, depends on this. Since the current drain on this line is constant, the requirements are met by a single high-stability reference tube.

The single-ended circuit of the amplifier necessitates some consideration of the effects of positive-line fluctuations if elaborate stabilizer circuits are to be avoided; thus the effect of a change of 1·5V on the +300V line is just about equivalent to a 1 per cent change in $V_1$ filament current if its effect on $V_1$ anode potential is uncompensated.

By arrangement of power feeds to $V_1$ and $V_2$ such that small variations are largely self-cancelling, the power supplies may be simplified to the extent that ordinary gas-filled reference tubes give adequate performance.

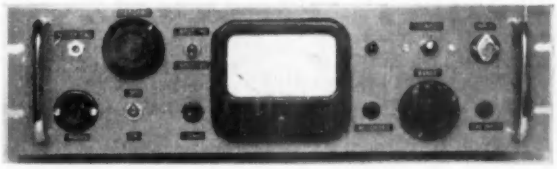
Warming-up effects also need consideration. Although $V_1$ filament can never be over-run, grid current can flow, particularly if the negative line voltage is established before the +300V supply. Previous work[2] with the CV2348 has established that such grid current is not harmful if limited to a few microamperes or so. The series grid resistor $R_8$ fulfils this requirement. The meter movement is disconnected during warm-up by a thermal delay switch.

## Performance

The performance of the circuit is very good, judged by normal direct-coupled amplifier standards. Grid current in the CV2348 is usually well below $10^{-14}$A, giving less than 1 per cent zero shift even with input resistors as high as $10^{12}\Omega$. Where sensitivities requiring resistors $>10^{12}\Omega$ are contemplated, the 'rate-of-rise' technique, using an input capacitor[8] is preferred. Departures from linearity are within the permitted values for a first-grade meter movement alone. Zero stability, at a full-scale voltage sensitivity of 2V is better than $\pm 1$ part in 1 000 over several hours, after an initial drift of $\simeq$1 to 2 per cent in the first ten minutes. Fig 5 shows a typical zero-stability record.

## Output Circuit for Low Sensitivity Meter

In some cases, it may be desirable to use a meter of lower sensitivity than 100$\mu$A; in such circumstances, the reduction in loop gain and variations of $V_1$ filament current caused by taking the meter feed from the virtual earth point would be intolerable. On the other hand, an additional cathode-follower feeding the meter is also undesirable, since it introduces a source of heater-cathode variation that is outside the feedback loop. A modified output circuit shown in Fig. 4 has been devised for use in such cases. The output is taken directly from $V_3$ cathode and returned to a potential divider connected to the +150V line via a zero-setting arrangement which renders the calibration sensitivity independent of zero-adjustment. Here zero stability may be somewhat



*The Complete Amplifier*

inferior, since it is necessary for both −150V and +150V lines to be stable, and a high-stability reference tube is thus employed for the latter source, and its loading should be arranged to be the same as that of the −150V tube. A zero stability of 1 part in 300 has been realized with this circuit.

## Conclusions

The designs presented have permitted the realization of direct-coupled electrometer amplifiers having a performance intermediate between that of earlier electrometer valve circuits and capacitive-modulation electrometers. This performance has been achieved with simple and economical circuits and without recourse to compensation techniques requiring frequent adjustment.


#### Acknowledgments

The author is indebted to his colleagues, particularly Mr. R. N. Bloomer and Mr. M. W. Jervis for helpful discussion and criticism, to Mr. R. Winkworth for much of the mechanical design and experimental work, and to Dr. T. E. Allibone, F.R.S., Director of the Research Laboratory, Associated Electrical Industries, for permission to publish this article.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# An Electronic Fault Locator for Overhead Lines

By G. Hitchcox*, M.I.E.E., M.Brit.I.R.E., and W. A. Neighbours*

*The general character of the problem is outlined and the comparative inadequacy of the various loop tests associated with the testing of underground cables is stressed. The body of the article describes an instrument which displays faults along the time-base trace of a cathode-ray oscilloscope together with a novel monitoring system accurately to determine their distance from the point of test. It is particularly suitable for the detection of multiple and intermittent faults. Finally, the alternative frequency modulation system based on the radio altimeter is briefly described.*

EVERY authority which operates overhead lines, either for power distribution or in communications systems, is well aware of the pressing need for rapid and accurate location of faults. The ever-present possibility of sudden faults and the importance of speed in effecting repairs may require the maintenance of expensive service teams, on duty day and night. Anything which can reduce the time spent in searching for trouble and which can indicate its character is of the highest value. In some overseas countries natural conditions make the problem exceptionally difficult; New Zealand is a case in point. Much of the territory is mountainous, densely covered in bush, and remote from roads or even tracks. Storms and gales are frequent, the wind velocity in some parts of the country greater than 40 mile/h for one-tenth of the year. Intervals between control points are often long, perhaps fifty or one hundred miles; a sparse population necessitates a simple and inexpensive mechanical construction. At the same time, adequate distribution of electric power and reliable communications systems are vital to the continued existence of scattered communities, and the need for efficient maintenance is correspondingly high.

*The Philips-EDAC electronic line fault locator*

Of the various methods commonly used for testing underground lines—the Blavier test, and the Murray, Varley, and Fisher loops—none is primarily suitable for aerial lines. They are inconvenient if the line includes short buried sections of different resistance, as often happens in practice; they are even more difficult to apply where branch lines are connected to the main run or where there are intervening or terminating transformers. The three loop tests require a second line for comparison, often not available. None of them easily detects intermittent contacts, probable results of growing foliage or overhanging branches of trees. All are confused by multiple faults, which appear as a single 'ghost' in a false position. None of them can indicate series faults at all. Complete rupture of the line, as distinct from high resistance joints, can be located by measurement of earth capacitance, but seldom accurately, since such capacitance is often variable, and again confusion is caused by either branches or intervening transformers.

In recent years there have appeared several instruments based upon radar techniques, specifically intended for the testing of aerial lines. The pulse injection method is the most common. If a series of short, widely separated, high amplitude pulses is injected into the line, the presence of either series or parallel faults induces reflections which, after suitable amplification, can be made to modulate (deflect vertically) the time-base trace of an oscilloscope, each stroke initiated by the generation of each transmitted pulse. Since the time interval between generation and reception of the reflection is a measure of the distance between the fault and the point of test, the oscilloscope can be directly calibrated in terms of distance. Each fault appears as a sharp vertical 'pip', its distance from the origin proportional to the distance of the fault along the line. The ability to view the whole length of the line at one time facilitates the detection of both multiple and intermittent faults. Either series or parallel faults can be observed, and since they appear in opposite sense, are readily distinguishable from each other.

### Pin-pointing the Fault

Indication of the presence of a fault is of little value unless its position can be accurately determined; its presence may well be obvious from its direct effects. With oscilloscopic display, accurate indication requires two facilities; expansion of the trace, or of that part of it where the fault 'pip' occurs, and a calibration or monitoring system, to reduce or eliminate errors due to variable amplifier gain, non-linearity in the oscilloscope tube, and to parallax in observing it. Expansion is necessary if a tube of practical size, say 12 to 15cm in diameter, is to cover distances of 100 miles or more; without it, one mile of line would occupy only about 1·2mm of the trace, too small for accurate observation.

In one calibration system, the time-base trace is

* *E.D.A.C. Ltd., Wellington, New Zealand.*

monitored by the addition of marker spikes, derived from a crystal controlled multivibrator oscillator. With a constant frequency, successive intervals between spikes indicate equal transmission distances; there is, however, some risk of confusion when testing long lines. If errors due to non-linearity and to inaccurate interpolation are to be reduced to insignificance, intervals between markers must be kept short, of the order of one to five miles. This postulates a large number of them and some uncertainty in deciding which is which, especially when looking for intermittent faults. It helps if every fifth or tenth marker is stressed, either by increasing its size or by inverting it, this demanding a considerably more complicated oscillator system.

In the instrument described below, a different system is adopted. The time-base is generated by a phantastron circuit, chosen because of its high inherent stability. The phantastron is triggered by the same oscillator as that which drives the injection pulse generator and is locked in such a way that the origin of each time-base stroke exactly coincides with the leading edge of the transmitted pulse. The duration, as distinct from the repetition frequency, of the time-base can be varied very sensitively and accurately by adjusting a multi-turn potential divider forming part of the phantastron circuit. In operation, the time-base is adjusted to a time greater than the transmission plus reflection interval of the line under test; if any fault pip is observed, the time-base is then 'peeled back'—that is, its duration reduced—until its end exactly coincides with the peak of the fault pip, as shown in Fig. 1. In view of the sharpness of the apex of the pip, this adjustment can be effected most sensitively, by shortening the time-base until the tip disappears. Fault distance is read by observing the setting of the multi-turn potential divider which, suitably

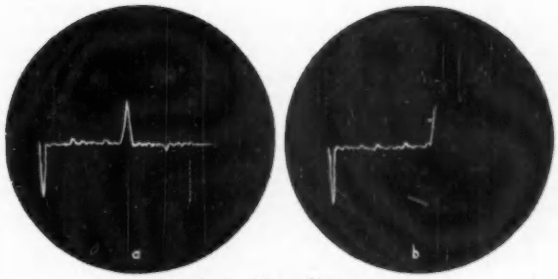


**Fig. 1. Double oscilloscope trace**

*(a) Time-base fully extended on 0 to 100 miles range with major parallel fault at 50 miles (b) Time-base retracted to peak of fault echo, its controls then indicating the distance to the fault*

arranged, can be directly calibrated in terms of distance. This combination of calibration monitoring system and time-base is believed to be unique; its advantage is the ease and sensitivity with which monitoring can be carried out.

## A Practical Instrument

The circuit of a recently introduced commercial instrument using the variable duration time-base principle is shown in Fig. 2. All power supplies have been omitted for simplicity, together with the gun circuits of the cathode-ray oscilloscope; they follow conventional practice.

The left-hand section of double-triode $V_1$ forms part of a blocking oscillator the pulsed output from which both triggers the phantastron time-base generator and drives the pulse injection amplifier valve $V_6$. Pulse duration is approximately 2·5$\mu$sec and repetition rate 200p/s, implying a

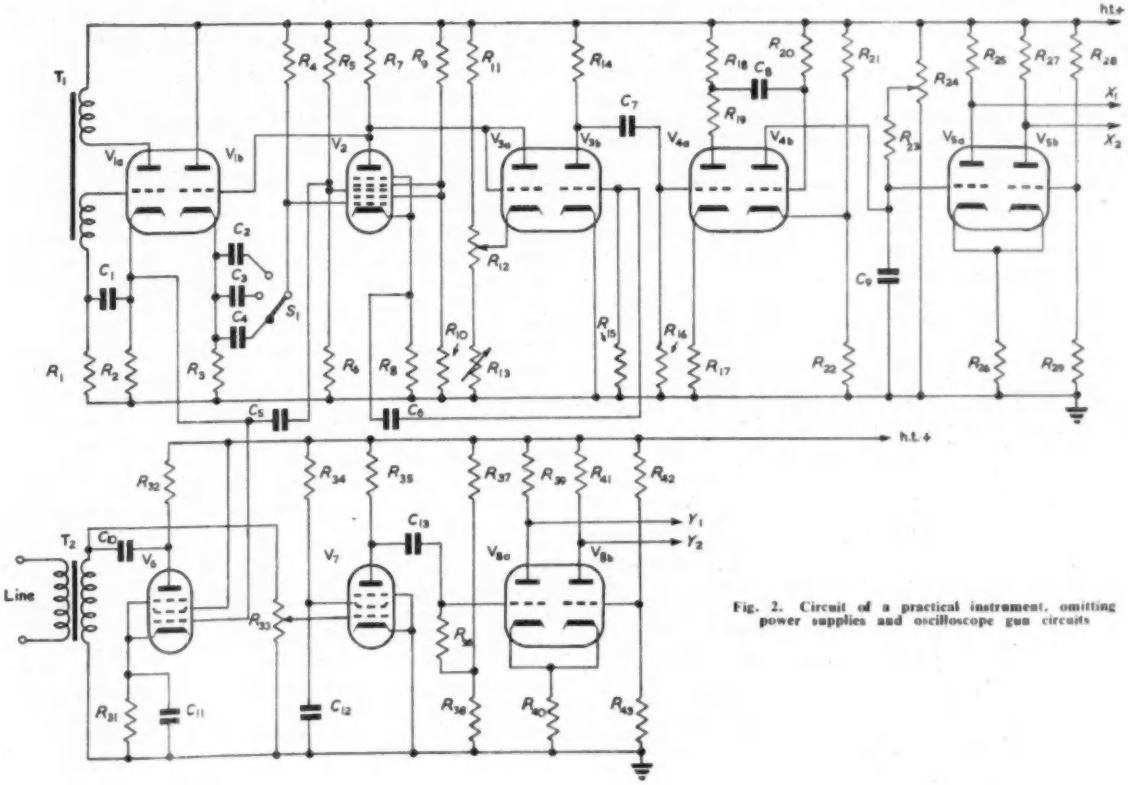


**Fig. 2. Circuit of a practical instrument, omitting power supplies and oscilloscope gun circuits**

mark-space ratio as far as injection into the line is concerned of 2·5 to 5 000 = 1 to 2 000. The upper limit to the pulse repetition rate is set by the longest length of line which the instrument is intended to test, in this case 300 miles, corresponding to a transmission plus reflection time of about 3·2msec. The separation interval between successive pulses must, of course, exceed this time to avoid overlap. The output from the pulse generator stage is taken through the isolating capacitor $C_5$ to the third grid of the heptode valve $V_2$ in the phantastron circuit, and to the control grid of high power pentode valve $V_6$, the output from which is fed into the line through matching transformer $T_2$. Normally $V_6$ is run at a very low anode current; its output pulse is negative-going in order not to paralyse the reflection receiver amplifier, described later.

The heptode $V_2$ together with cathode-follower $V_{1b}$ and locking diode $V_{3a}$ (a strapped triode) forms the phantastron time-base generator. The merits of a phantastron are: its ability to generate very widely variable 'mark' intervals, high stability of generated interval against power supply changes, and a high degree of linearity. The stability of the 'mark' interval is such that no special precautions need be taken to control either heater or h.t. supplies. Linearity—that is, a uniform relationship between generated time interval and setting of the adjustment control—is necessary if this control is to be accurately calibrated in terms of distance. Three time ranges are provided, according to the value of the timing capacitance selected by the range switch $S_1$, the corresponding distance ranges being 0·3 to 10 miles, 3 to 100 miles, and 10 to 300 miles. The continuously variable control $R_{12}$ is a 10-turn spiral potentiometer directly calibrated in miles; its setting can be adjusted and read to 1 part in 1 000 of its maximum value. A degree of flexibility is provided by the pre-set adjustment $R_{11}$ to allow the instrument to be directly calibrated for the actual line under test; it is set up by adjusting it accurately to indicate the distance of some known point, such as the end of the line.

It may be stressed that adjustment of the phantastron controls affects only the mark-to-space ratio of its output; repetition rate is fixed by the pulse generator which triggers it, and remains constant at 200p/s. The duration of the mark interval is variable over the three ranges from about 3·2msec to 3·2 msec. The nearly rectilinear output is heavily amplified by the triode amplifier valve $V_{3b}$ and is then further 'squared' by the following limiter stage based upon valve $V_{4a}$, the gain of which is reduced by tapping down the anode load. The signal, now nearly perfectly rectilinear, is fed to triode $V_{4b}$, its anode-cathode impedance directly in parallel with the sweep generation capacitor $C_9$ which, during the 'space' interval, is thereby practically short-circuited. In the 'mark' period, the heavy negative signal applied to the grid of $V_{4b}$ transforms it to an open-circuit and $C_9$ is charged from the positive h.t. supply through $R_{22}$ at a rate determined by the adjustment of sweep expansion control $R_{24}$. The rate of rise is substantially constant since the level at which $C_9$ is short-circuited, at the end of the 'mark' period, is normally small relative to the positive voltage derived from $R_{24}$. The effect of $R_{24}$ is to vary the amplitude of the series of triangular signals developed across $C_9$, their duration being determined by the adjustment of the phantastron. These signals are applied to the phase-splitter stage based upon double-triode $V_5$, the balanced outputs from which are directly connected to the horizontal deflexion plates of the oscilloscope tube.

Reflection signals induced by faults in the line return through the matching transformer $T_2$ and are controlled by the continuously variable attenuator $R_{33}$. After amplification by high gain pentode $V_7$, they are applied to phase-splitter $V_8$ and then fed to the vertical deflexion plates of the oscilloscope. It has been mentioned that the output from injection amplifier pentode $V_6$ is such that the polarity of the high amplitude injection pulse is negative relative to earth, to avoid paralysis of the receiver. During the 'space' interval, the beam current of the cathode-ray tube is cut off, the connexion from the pulse squarer stage to the grid of the tube not being shown in this simplified circuit.

**Operation**

The instrument is connected to the line under test, the operating conditions of the cathode-ray tube adjusted in the ordinary way, and the phantastron controls set so that the time-base trace covers a distance rather more than the total length of the line. The presence of discontinuities in the line such as faults induces sharp 'pips' on the horizontal trace, in the same sense as the transmitted pulse for series faults, and opposite to it for parallel faults. The distance separating any fault from the point of test can be determined by shortening the time-base until it ends exactly on the sharp tip of the corresponding 'pip', the setting of phantastron controls $S_1$ and $R_{12}$ then directly indicating distance. Sensitivity of adjustment is such that any fault can be located to within 1 500ft, much finer discrimination being possible on the shorter ranges, especially where the operator is familiar with the characteristics of the line under test.

Where distance to the fault is small relative to the maximum of the range in use, the horizontal trace can be expanded with advantage, using $R_{24}$, which determines time-base amplitude. To adjust the instrument as a whole to the characteristics of any particular line, the phantastron controls should be set to indicate the separation distance of some accurately known point; the master trimmer $R_{12}$ is then adjusted to make the end of the time-base trace exactly coincide with the tip of the corresponding reflection 'pip'. The instrument will then correctly indicate this or any other distance within its working range.

**Accuracy and Limitations**

One merit of this system is that it avoids the need for either lineal measurement of the tube trace or interpolation, its accuracy also being unaffected by variation of gain in either deflexion amplifier or by non-linearity in the oscilloscope tube itself. Operational accuracy is primarily determined by the stability and linearity of the phantastron time-base generator and while such stability cannot reach the perfection of a crystal-controlled monitoring oscillator, accuracy of operation can be rapidly and simply checked against a single known point on the line actually under test. In this case, a certain degree of flexibility can be of positive advantage, since transmission velocity is slightly dependent on the physical construction of the line.

An instrument of this kind cannot reveal potential as distinct from actual faults; for example, it cannot detect the presence of obstructions close to the line but not touching it, which might be found from a high voltage flash-over test. Nor can it display high resistance parallel faults exceeding 10kΩ, perhaps due to damaged but not broken insulators, since the reflection signal then becomes too small for observation. The use of a pulsed test signal of very low average power content has at the same time some advantages; it cannot cause personal shock or damage to ordinary apparatus inadvertently connected to the line, and it is unlikely to induce serious interference in other lines which may be running parallel to that under test.

Finally, while this instrument can detect either series or major parallel faults, or combinations of them, it obviously cannot reveal faults on the far side of a total rupture of the line.

### Frequency Modulation Systems

In conclusion, a brief reference to the very interesting alternative frequency modulation system may be of interest. The basic principle is the same, indication of fault distance by measurement of transmission time, but the mechanism is very different. A continuous constant amplitude radio frequency signal is injected into the line. Its frequency is modulated on a sawtooth pattern, increasing at a constant rate $df/dt = M$ for a period greater than the transmission plus reflection time of the line under test, then suddenly reverting to its original value to start the modulation cycle again. As before, the presence of a fault induces a reflected signal; when this reaches the instrument its frequency $f_r$ will be lower than the transmission frequency $f_t$, the difference given by:

$$f_t - f_r = 2tM$$

where $t$ is the transmission time from the instrument to the fault. This difference frequency can be extracted by heterodyning and measured, the result indicating transmission time and hence fault distance. This method, borrowed from the radio altimeter, is not in very wide use since, without an oscilloscope display to indicate spatial relationships, it cannot conveniently detect either multiple or intermittent faults.

**Acknowledgment**

This instrument was originated by the second author and is manufactured by E.D.A.C. Limited (a Philips company) in Wellington, New Zealand, and thanks are given to that company for permission to describe it.

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# Measurement of the Characteristic Impedance of a Coaxial Cable

By L. B. D'Alton*, M.E., A.M.I.E.E.

*A method is described for measuring the characteristic impedance of a coaxial cable and the velocity of propagation, the only equipment required being a radio receiver, a signal generator and a calibrated capacitor.*

THE input impedance $Z_s$ of a dissipationless two-wire transmission line terminated in a load $Z_R$ is given by the well-known expression

$$Z_s = R_c \frac{Z_R + jR_c \tan \beta d}{R_c + jZ_R \tan \beta d} \quad \ldots\ldots (1)$$

where $R_c$ is the characteristic resistance, $\beta$ the phase shift per unit length and $d$ the length. If the line is open-circuited ($Z_R = \infty$) this reduces to

$$Z_s = -jR_c \cot \beta d \quad \ldots\ldots (2)$$

and if the line is short-circuited ($Z_R = 0$) it reduces to

$$Z_s = jR_c \tan \beta d \quad \ldots\ldots (3)$$

Thus, a method commonly prescribed for the measurement of $R_c$ is that of measuring $Z_s$ first with the line open-circuited and secondly with the line short-circuited. Then

$$R_c^2 = Z_{s(o.c.)} \cdot Z_{s(s.c.)} \quad \ldots\ldots (4)$$

However, this system (or any other system based on equation (1) barring a v.s.w.r. technique necessarily excluded in the case of a coaxial cable) calls for an r.f. impedance measurement; the measurement of $Z_s$ at audio frequencies would lead to intolerable errors. To meet the case where an r.f. bridge, slotted line, or other standard method is not available, or as an alternative to its use, the author has devised the following method.

### Method

It is obvious from equation (2) that providing cot $\beta d$ is positive, i.e., providing $\beta d < 90°$, the cable looks like a pure capacitance of value $C$ given by

$$(1/\omega C) = R_c \cot \beta d \quad \ldots\ldots (5)$$

The method of determining $C$ experimentally is indicated in Fig. 1. A modulated signal is fed through $R_1$, and the switch $S$ either to the cable (open-circuited) or to the calibrated capacitor $K$ and the latter is adjusted until the meter $M$ connected to the audio output of the receiver gives the same reading for either position of $S$. The effective capacitance of the cable is then that indicated by $K$. It remains to determine $\beta d$, but before passing on there are some points worth noting.

$R_1$ forms a potential divider with the cable and/or $K$ and it can easily be shown that in order that a given disparity between the apparent capacitance of the cable and the capacitance of $K$ should produce the largest possible percentage change in $M$ the value of $R_1$ should be at least

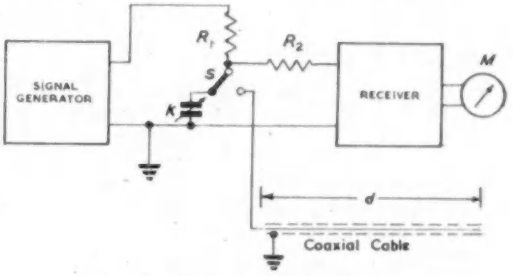



**Fig. 1. Arrangement of the equipment**

five times the reactance of $K$. The function of $R_2$ is simply to prevent the input capacitance of the receiver from swamping $K$ and/or to prevent $K$ from tuning the receiver, which effect if permitted results in an ambiguity in the setting of $K$. It should therefore also be large compared with the reactance of $K$.

It is further worth noting that all the advantages of a substitution method accrue viz., the impedance seen by the signal generator is unaffected by the setting of $S$ as is also the impedance seen by the receiver; errors arising from a variation of these quantities are thus avoided. Non-linearities in the receiver introduce no inaccuracy as they

* *University College, Dublin.*

would if differing voltages were being measured; it is not even necessary that the receiver should be stable.

In regard to the determination of $\beta d$ let it be assumed first that the velocity of propagation (i.e., the phase velocity) along the cable is known. (In point of fact the manufacturers often specify this quantity to a fair degree of accuracy though the characteristic impedance is specified to no better than 10 per cent). Then, if the velocity is $p$ per cent of the velocity of light $c$ and if $\lambda$ is the wavelength

$$\lambda = (pc/f)$$

and since

$$\beta = (360/\lambda)^\circ$$

$$\beta d = (360fd/pc)^\circ \quad \ldots\ldots\ldots\ldots\ldots (6)$$

Thus cot $\beta d$ is known and since $C$ and $\omega$ are known $R_c$ may be determined from equation (5).

The quantities $f$ and $d$ must, of course, be chosen so that $\beta d < 90^\circ$ and it is desirable that $\beta d$ should lie between $10^\circ$ and $80^\circ$. It is also desirable that the cable should be so long that inaccuracies in the measurement of its length introduce no appreciable error. A reasonably long cable also meets another desideratum viz., that $f$ should be kept as low as possible; for high values of $f$ may introduce losses in the variable capacitor $K$ unless it is of extra high quality and are also liable to introduce errors as the circuit configuration is changed by the switch. Connexions to the latter should be kept short.

On the other hand if the cable is very long the error introduced by the attenuation will become serious (see Appendix).

The author chose a value of 4m for $d$ for the Hackethal (German) Type Al 0·6/7·2 100Ω cable and measured $R_c$ at seven different frequencies between 1Mc/s and 10Mc/s. The manufacturers specified $p$ as 66 per cent. The average result was 100·5Ω and the maximum deviation from this value was as little as 0·6Ω, i.e., 0·6 per cent.

### Measurement of Velocity

The only remaining problem is the determination of $\beta d$ or the propagation velocity when the latter is unknown.

Suppose that at a frequency $f_1$ the cable has an effective capacitance $C_1$ and that the value of $\beta$ is $\beta_1$. Then equation (5) becomes

$$\frac{1}{2\pi f_1 C_1} = R_c \cot \beta_1 d \quad \ldots\ldots\ldots\ldots\ldots (7)$$

Similarly at a frequency $f_2$

$$\frac{1}{2\pi f_2 C_2} = R_c \cot \beta_2 d \quad \ldots\ldots\ldots\ldots\ldots (8)$$

$$\therefore \quad \frac{f_2 C_2}{f_1 C_1} = \tan \beta_2 d \cot \beta_1 d \quad \ldots\ldots\ldots\ldots (9)$$

This equation can be solved only by a graphical method and graphical methods are tedious. But if $f_2$ is made equal to $2f_1$ then equation (6) shows that $\beta_2 = 2\beta_1$ and equation (9) becomes

$$2C_2/C_1 = \tan 2\beta_1 d \cot \beta_1 d$$

$$= \frac{2 \tan \beta_1 d}{1 - \tan^2 \beta_1 d} \cot \beta_1 d$$

$$= \frac{2}{1 - \tan^2 \beta_1 d}$$

$$\therefore \tan \beta_1 d = \sqrt{(1 - (C_1/C_2))} \quad \ldots\ldots\ldots (10)$$

from which the propagation velocity may be computed if required.

### Condition For Minimum Error

It is worth noting again that if the frequency $f_1$ is low, tan $\beta_1 d$ is small and from equation (10) $C_1$ is very nearly equal to $C_2$. A very small error in $C_1$ or $C_2$ will then give rise to a very large error in $\beta_1 d$. Thus, if $C_1$ and $C_2$ differ by only 1 per cent then an error of $-1$ per cent in $C_1$ gives rise to an error of $+40$ per cent in tan $\beta_1 d$. If, however, $C_2$ is of the order of twice $C_1$ then an error of $-1$ per cent in $C_1$ gives rise to an error of less than $+1$ per cent in tan $\beta_1 d$. Therefore for high accuracy tan $\beta_1 d$ should be not less than $1/\sqrt{2}$

$$\therefore \quad \beta_1 d \geqslant 35{\cdot}3^\circ$$

$$\therefore \quad f_1 d \geqslant (pc/10)$$

If $p$ is assigned a representative value of 75 per cent then in general $f_1 d$ should be arranged to be of the order of $23 \times 10^6$m/sec.

Using the method outlined the author derived a value of 66·4 per cent for $p$ as compared with the manufacturer's figure of 66 per cent.

Measurements of $R_c$ and $p$ made on a cellular polythene 75Ω television downlead cable yielded similar results.

### Summary


The procedure may be summarized as follows:

Arrange the circuit as in Fig. 1 and having chosen a suitable length of cable $d$ (preferably not less than about 2m) set the signal generator and receiver each to a frequency $f_1$ such that

$$f_1 d \simeq 23 \times 10^6 \text{m/sec}$$

and make $R_1$ and $R_2$ of the order of 1·5kΩ each. Adjust $K$ until the reading of $M$ is independent of the switch position. If the propagation velocity is known $R_c$ may now be calculated from equation (5). If not, reset the signal generator and receiver to a frequency $f_2 = 2f_1$ and adjust $K$ as before. The value of $R_c$ may now be computed from equations (10) and (5) and the propagation velocity, if required, from equation (10).

It is, of course, necessary that the r.f. losses in $K$ should be negligible and that its calibration should be accurate. (If such a capacitor is not available an ordinary 500pF tuning capacitor may be used and measured at any setting against a 1kc/s bridge or any suitable standard). It is also necessary that the frequency calibration of the signal generator should be accurate.

It is shown in the Appendix that the error involved in the assumption that the cable is dissipationless is negligible.


### Appendix

The input impedance of a cable which is not dissipationless is given by

$$Z_s = Z_c \coth (\alpha + j\beta)d \ \ldots \text{ (open-circuited)}$$

where $Z_c$ is the characteristic impedance and $\alpha$ the attenuation in nepers per unit length. This may be written

$$Z_s = Z_c \frac{1 + j \tanh \alpha d \tan \beta d}{\tanh \alpha d + j \tan \beta d}$$

Even at 10Mc/s the highest attenuation for the smallest diameter cellular polythene television cable is of the order of 0·0057N/m. If $p$ and $d$ are assigned representative values of 80 per cent and 4m respectively then $\alpha d = 0{\cdot}0228$N and $\beta d = 60^\circ$; and since $Z_c$ is very nearly the same as $R_c$ for a low-loss cable, substitution of these values gives

$$Z_s = R_c(0{\cdot}031 - j\,0{\cdot}577)$$

The operator will automatically adjust $K$ to make its reactance equal to the modulus of $Z_s$, i.e.,

$$(1/\omega C) = 0{\cdot}5781 R_c$$

The true value of $R_c$ is thus $1/0{\cdot}5781\omega C$ and the operator proceeding on the assumption of a dissipationless cable measures it as $1/\omega C \cot 60^\circ = 1/0{\cdot}5774\omega C$.

Thus the apparent value of $R_c$ is

$$\frac{0{\cdot}5781}{0{\cdot}5774} R_c = 1{\cdot}001 R_c$$

so that the error is 0·1 per cent. This error increases as the cable length is increased, but is still only 0·2 per cent for $d = 13$m.

# A Versatile Pulse Pattern Generator

By Peter H. Cutler*, B.Sc., and L. R. Peters*

*Two independent pulse pattern generators are used to produce any sequence of pulses of either polarity; either sequence contains up to ten pulses, and the pulse duration may be varied from 45μsec to 1sec.*

*The two separate patterns may be combined to give a third pattern whose maximum length is ninety pulses.*

DURING an experimental investigation into the use of multi-cathode gas tubes in computer type circuits, the pulse pattern generator described below, was designed and constructed.

Two multi-cathode selector gas tubes are used each driven by a common variable-frequency oscillator.

Each produces a pattern of pulses whose frame length may separately be varied, the patterns being determined by means of selector switches on the front panel. These outputs are available with either polarity and if desired the pulse length may be reduced so as to produce a gap between adjacent pulses.

Suitable combining circuits of the type commonly used for carrying out logical operations in electronic computers enable pattern cycles up to ninety pulses in length to be obtained. The generator has been in operation in the authors' laboratory and has been found to be very useful and reliable.

* *S.R.D.E.*

**Brief Circuit Description (see Figs. 1 and 2)**

(a) THE COUNTERS

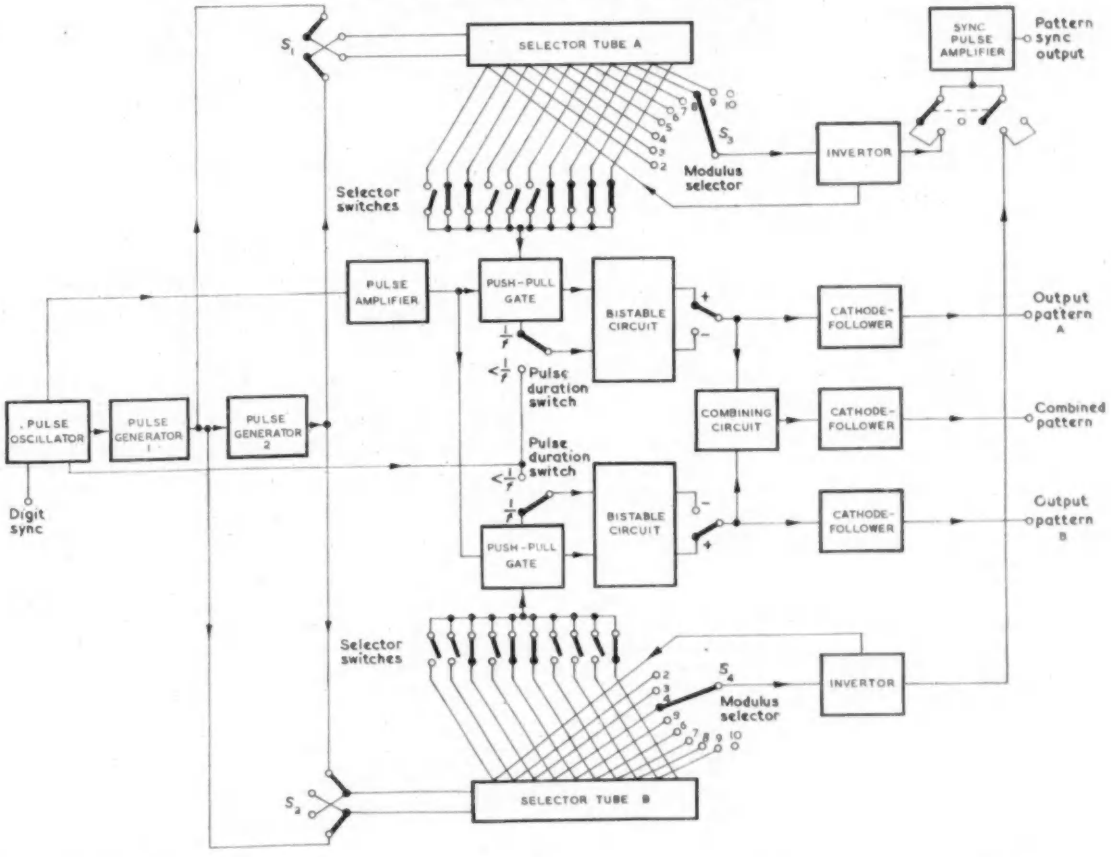
The basic unit of the pattern generator consists of a counter type circuit which is driven by periodic pulses. The Ericsson GS10D multi-cathode selector tube has been chosen for the counter and acts as a pulse pattern generator. This valve and suitable circuits for driving it have been described in the literature[1].

A pair of pulses to drive the GS10D tubes is derived from a multivibrator ($V_1$ and $V_2$), whose frequency may be varied from 1c/s to 22kc/s. These pulses cause a single "glow" to rotate about the anode disk, the direction of rotation being determined by the sequence of the drive pulses.

Switches $S_1$ and $S_2$ have been inserted into the drive leads of each valve so that each may be driven in either direction, as desired.

When a 'glow' invests one of the ten output cathodes, a positive voltage pulse occurs across the cathode load

**Fig. 1. Block schematic diagram of the pattern generator**



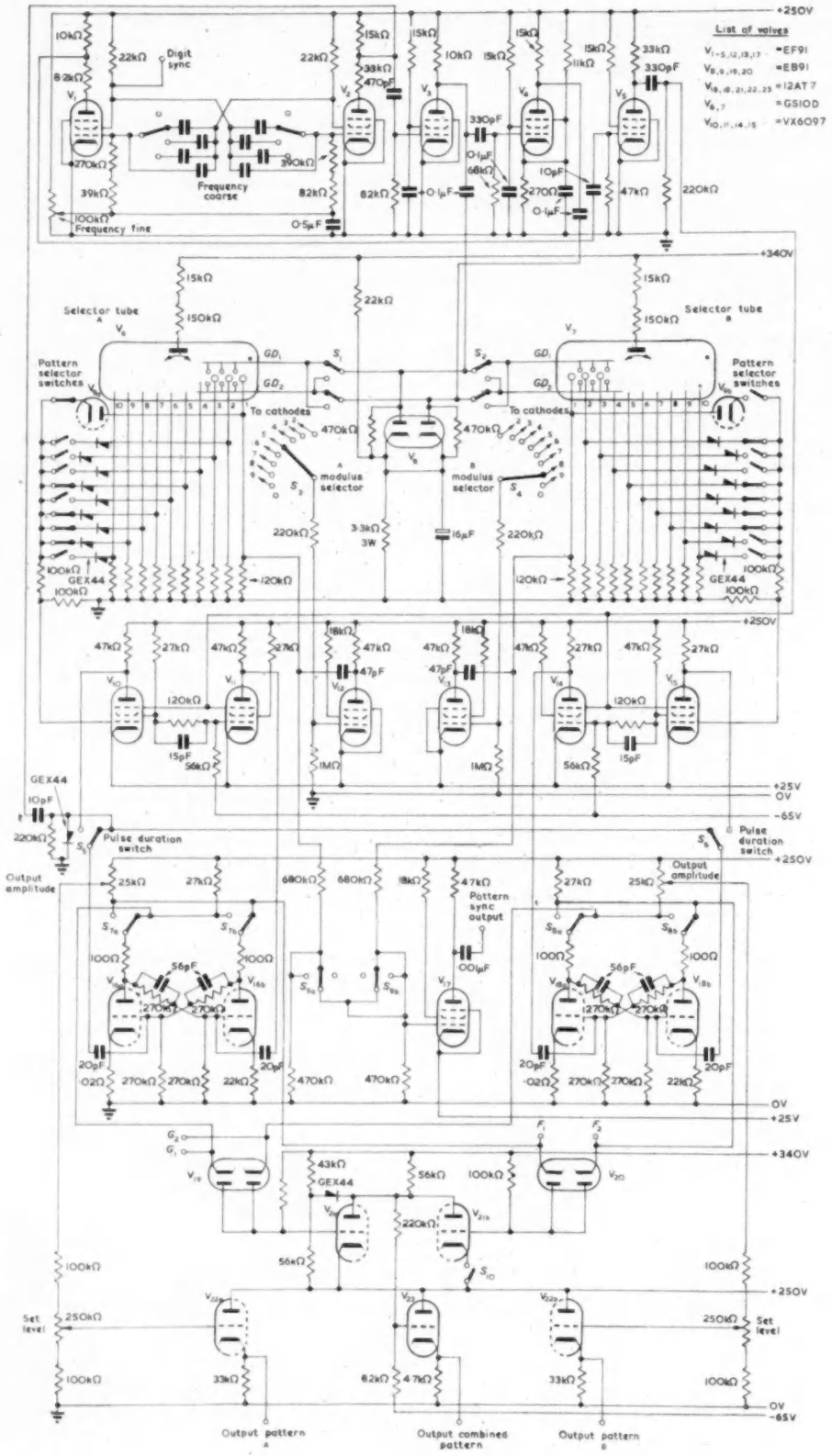
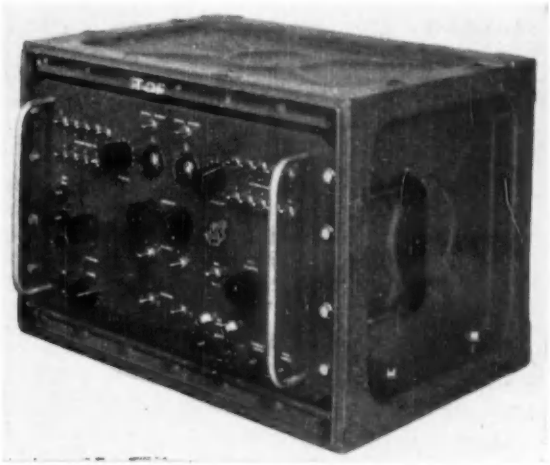



**Fig. 2. Circuit diagram of the pattern generator**

resistor. Any cathode may be connected via a rectifier and switch to a common line, the rectifiers preventing coupling between cathodes. Thus any pattern of pulses up to a maximum of ten may be obtained by setting the appropriate switches associated with a counter. Since two counters are incorporated, two separate patterns may be obtained.

The modulus of a counter may be varied from two to ten by selecting an output from any cathode (switches $S_3$ or $S_4$) and using it, after suitable amplification and inversion, to reset the 'glow' in that counter to its first position.

The outputs of the counters are separately used to gate clock pulses derived from the multivibrator, which, in turn, control bistable circuits. Variable amplitude output pulses of both polarity are obtained from these circuits and fed to cathode-followers ($V_{22a}$ and $V_{22b}$) to present a low output impedance at the terminals. If desired, pulses which occur between the normal clock pulses may be fed (via switches $S_5$ and $S_6$) into one input of the bistable circuits, so causing a return to zero at the end of each output pulse.



*The complete pattern generator*

### (b) The Combining Circuits

The usefulness of the pattern generator has been very greatly increased by the inclusion of simple diode combining circuits ($V_{19}$ and $V_{20}$). The three basic functions which the diodes perform are (a) an AND gate, (b) an OR gate, and (c) a NOT EQUIVALENT gate. To avoid confusion in terminology, truth tables of these operations are shown in Table 1.

As an example, imagine that the counters have moduli of six and seven, and are producing outputs as shown diagrammatically in Fig. 3(a) and 3(b) (an X represents a mark, either positive or negative). The voltage at the anodes of $V_{19}$ (point C) (Fig. 2) will only rise positively when both $G_1$ and $G_2$ are positive at the same time, so that if the waveforms are considered to be a series of positive marks, the voltage at C (shown diagrammatically in Fig. 3(d) will represent the effect of performing an AND operation. Similarly if the waveform is considered to consist of negative marks the voltage at C will represent the effect of an OR operation. Either polarity of mark may be obtained by selecting the appropriate anodes of the bistable circuits by means of switches $S_7$ and $S_8$. Fig. 3(d) and (e) show the possible outputs which may be obtained using the inputs shown in Fig. 3(a) and (b).

As mentioned above, either counter may be reversed in direction. Thus, taking the examples given in Fig. 3, the output shown in (b) may be reversed giving the output 3(c). Using, then, the outputs 3(a) and (c), the combining circuit will give 3(f) or (g). This reversing facility therefore provides a simple and quick method of obtaining different patterns containing the same number of marks and spaces. The appendix gives formulæ enabling the numbers of marks and spaces to be quickly calculated.

The triode $V_{21a}$ acts as a slicer and its output is passed to a cathode-follower $V_{23}$.

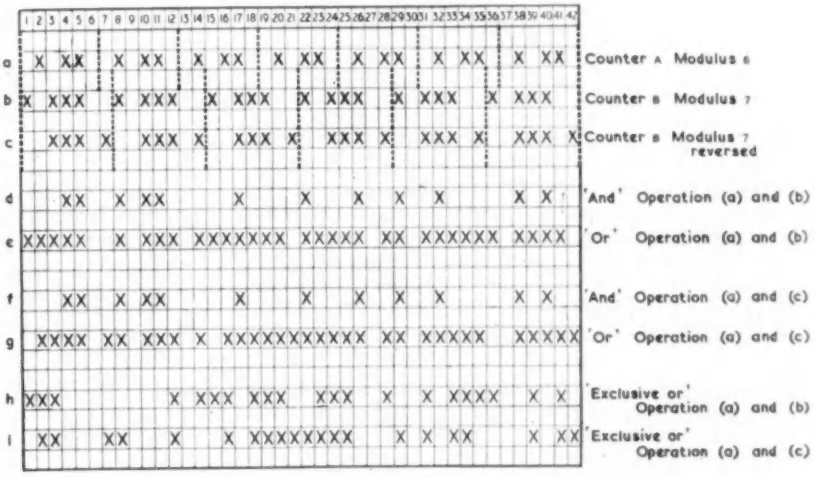
By incorporating another diode gate and feeding to this second gate (see Fig. 2, $F_1$ and $F_2$) the inverted patterns of the waveforms applied to the first, the voltage at the anodes of $V_{20}$ (point D) will only rise positively when both inputs to the first gate are negative at the same time. Thus the waveforms at C and D taken together will indicate the effect of a NOT EQUIVALENT operation on the input waveforms. By closing the switch in the cathode lead of $V_{21b}$ the inverted output of the addition of points C and D is obtained at the common anode of $V_{21}$. Fig. 3(h) and (i) show the outputs which may be obtained by using the waveforms shown in Fig. 3(a) and (b) or (c) as inputs.

As an additional refinement, direct current couplings are used from the bistable circuits onwards so that the low frequency content of the waveform is maintained, the actual level of the positive portion of the output waveforms being

**TABLE 1**

| INPUT | | OUTPUT | | |
|---|---|---|---|---|
| A | B | AND | OR | NOT EQUIVALENT |
| 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 1 |
| 1 | 0 | 0 | 1 | 1 |
| 1 | 1 | 1 | 1 | 0 |

**Fig. 3. Example of outputs obtainable**


1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42
a
b
c
d
e
f
g
h
i
Counter A Modulus 6
Counter B Modulus 7
Counter B Modulus 7 reversed
'And' Operation (a) and (b)
'Or' Operation (a) and (b)
'And' Operation (a) and (c)
'Or' Operation (a) and (c)
'Exclusive or' Operation (a) and (b)
'Exclusive or' Operation (a) and (c)

adjustable by means of the preset controls in the grid circuits of $V_{22}$.

The photograph shows the external appearance of the pattern generator. The GC10D's are mounted horizontally so that the glow on the electrodes of the valves may be observed from the front, thus affording a quick method of checking the length of the two basic pattern cycles.

### Appendix

It will be observed in Fig. 3 that each position of the modulus six counter coincides once and once only with each position of the modulus seven counter. This is obviously true in general.

Let the counter moduli be $m_1$ and $m_2$

Let the number of marks be $n_1$ and $n_2$
and the number of spaces be $s_1$ and $s_2$

Then $n_1 + s_1 = m_1$ and $n_2 + s_2 = m_2$

The total length of the cycle $= m_1 \cdot m_2$

'AND' Operation

The number of marks present $= n_1 \cdot n_2$

The number of spaces present $= m_1m_2 - n_1n_2$

'OR' Operation

The number of marks present $= m_1m_2 - s_1s_2$

The number of spaces present $= s_1s_2$

'NOT EQUIVALENT' Operation

The number of marks present $= m_1m_2 - s_1s_2 - n_1n_2$

The number of spaces present $= s_1s_2 + n_1n_2$

N.B.—If the two moduli $m_1$ and $m_2$ contain a common factor the total length of the cycle will be proportionately reduced, e.g. moduli 6 and 8 give a cycle of

$$\frac{6 \times 8}{2} = 24.$$

Table 2 shows the number of marks and spaces for the examples shown in Fig. 3.

**TABLE 2**

$m_1 = 6,\ m_2 = 7 \quad \therefore$ total length $= 42$

$n_1 = 3,\ n_2 = 4 \quad \therefore\ s_1 = 3,\ s_2 = 3$

| OPERATION | FORMULA FOR NO. OF MARKS | EXAMPLE NO. OF MARKS |
|---|---|---|
| AND[1] | $n_1 \cdot n_2$ | 12 |
| OR[2] | $m_1m_2 - s_1s_2$ | 33 |
| NOT EQUIVALENT[3] | $m_1m_2 - s_1s_2 - n_1n_2$ | 21 |

1. (See Fig. 3(d) and (f))
2. (See Fig. 3(e) and (g))
3. (See Fig. 3(h) and (i))

**REFERENCE**

1. Cold Cathode Tubes (Ericssons Telephones Ltd).

# A Chart for Return Loss Determination

By L. Kitajewski*, B.Sc.

*Formulæ are derived and a set of curves plotted which enable the return loss or reflection coefficient to be quickly determined from bridge measurements of impedances.*
*Merits of the chart are discussed.*

DESIGN of telecommunication equipment involves, in most cases, matching to a specified impedance.

The degree of matching is usually called 'return loss' and is expressed in decibels.

Return loss can be measured quickly and accurately with the help of a return loss tester arranged in a special circuit. This method, however, is more suitable for production testing purposes than for development work where information as to the actual modulus and angle of impedance are often required. In development work it is more customary to measure the impedance by a bridge and then find the return loss value from suitable charts.

The purpose of this article is to discuss a chart for use with parallel bridge measurements of impedance.

Reflection coefficient, $\rho$, is a measure of the degree of matching, but a more convenient way of expressing that degree of matching is to take $20\log 1/\rho$, which is then called return loss.

As,

$$\rho = \frac{Z_o - Z_R}{Z_o + Z_R}$$

where $Z_o$ = characteristic impedance, and $Z_R$ = terminating impedance.

Hence, return loss $= 20 \log \left|\frac{Z_o + Z_R}{Z_o - Z_R}\right|$

Let $\left|\frac{(Z_o + Z_R)}{(Z_o - Z_R)}\right| = N$ and $Z_o = R_o + jX_o$, $Z_R = R + jX$

$$\therefore N = \left|\frac{(R_o+R)+j\,(X_o+X)}{(R_o-R)+j\,(X_o-X)}\right| \quad \therefore N^2 = \frac{(R_o+R)^2+(X_o+X)^2}{(R_o-R)^2+(X_o-X)^2} \qquad \ldots\ldots\ldots\ldots (1)$$

From equation (1), on multiplying out,

$$N^2R_o^2 - 2RR_oN^2 + N^2R^2 + N^2X_o^2 - 2XX_oN^2 + N^2X^2 = R_o^2 + 2RR_o + R^2 + X_o^2 + 2XX_o + X^2$$

$$\therefore R^2(N^2-1) + X^2(N^2-1) - 2R(N^2+1)\ R_o - 2X\,(N^2+1)\,X_o + R_o^2\,(N^2-1) + X_o^2\,(N^2-1) = 0$$

$$\therefore R^2 + X^2 - 2R\,\frac{N^2+1}{N^2-1}\,R_o - 2X\,\frac{N^2+1}{N^2-1}\,X_o + R_o^2 + X_o^2 = 0 \qquad \ldots\ldots\ldots\ldots (2)$$

which is an equation of a circle with $R$ and $X$ variables and $N$, $R_o$, $X_o$ constants.

To find the co-ordinates of the centre to this circle and its radius equation (2) can be transformed to:

* The General Electric Co. Ltd.

$$\left(R - \frac{N^2+1}{N^2-1}R_o\right)^2 + \left(X - \frac{N^2+1}{N^2-1}X_o\right)^2$$

$$= \left(\frac{N^2+1}{N^2-1}R_o\right)^2 + \left(\frac{N^2+1}{N^2-1}X_o\right)^2 - (R_o^2 + X_o^2) \quad \ldots (3)$$

From equation (3) co-ordinates of the centre are obtained:

$$\left(\frac{N^2+1}{N^2-1}R_o,\ \frac{N^2+1}{N^2-1}X_o\right)$$

and the radius $= \sqrt{\left[\left(\frac{N^2-1}{N^2+1}\right)(R_o^2+X_o^2) - (R_o^2+X_o^2)\right]}$

if $Z_o$ is purely resistive, then $X_o = 0$

hence, co-ordinates of the centre are: $\left(\frac{N^2+1}{N^2-1}R_o,\ 0\right)$

and radius $= \sqrt{\left[\left(\frac{N^2+1}{N^2-1}R_o\right)^2 - R_o^2\right]}$

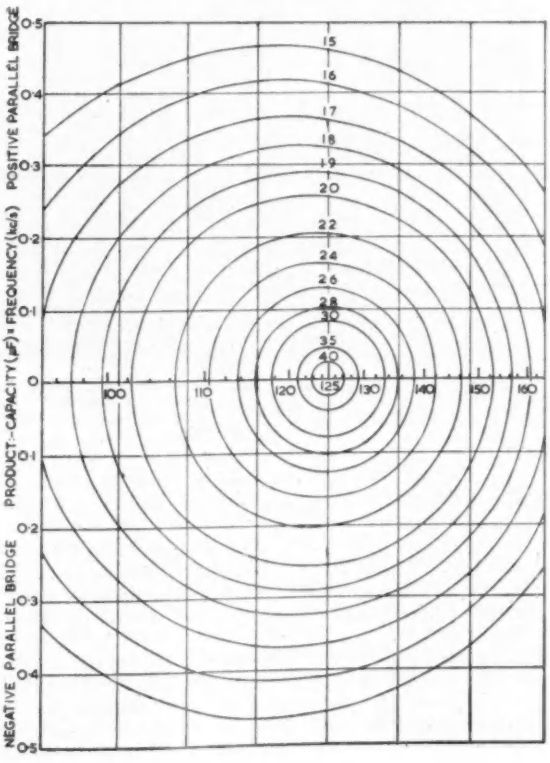
$$= \sqrt{\left[\frac{(N^2+1)^2R_o^2 - R_o^2(N^2-1)^2}{N^2-1}\right]}$$

$$= \sqrt{\left[\frac{2 \times 2N^2R_o^2}{(N^2-1)^2}\right]} = \frac{2N}{N^2-1}R_o$$

If a parallel bridge is used, it will measure resistance in parallel with reactance, then

$$\text{Return loss} = 20 \log \left|\frac{Y + Y_o}{Y - Y_o}\right| \quad \ldots\ldots\ldots\ldots (4)$$

Fig. 1. Return loss curves with respect to 125 ∠0°Ω. Parallel bridge




Where $Y$ and $Y_o$ are admittances $Y_o = G_o + jB_o$, $Y = G + jB$

Where $G$ = conductance. $B$ = susceptance.

Denoting $\left|\frac{Y + Y_o}{Y - Y_o}\right| = N$ and proceeding as previously one obtains an equation of a circle for a constant value of $N$. The co-ordinates of the centre to the circle are now given by

$\left(\frac{+1}{N^2-1}G_o,\ 0\right)$ and radius by $\frac{2N}{N^2-1}G_o$.

For impedance of 125 ∠0°, $Y_o = (1/125)$.

Also, if one measures reactance in terms of capacitance only, then

$B = \omega C = 2\pi fC$ or if $f$ is in kc/s and $C$ in μF

$B = 2\pi \times$ kc/s $\times$ μF $\times 10^{-3}$ and $\frac{B}{2\pi \times 10^{-3}} =$ kc/s × μF

For a return loss of 15dB $N = 5{\cdot}62$ from equation (4). Hence,

Centre $= \left(\frac{5{\cdot}62^2 + 1}{5{\cdot}62^2 - 1} \times (1/125) \times \frac{1}{2\pi \times 10^{-3}},\ 0\right)$

or (1·356, 0)

and radius $= \frac{2N}{N^2-1} \times (1/125) \times \frac{1}{2\pi \times 10^{-3}} = 0{\cdot}468$

Hence the scale is chosen to represent 0·1 of the product (kc/s) × (μF) by 1 inch.

Product of (kc/s) × (μF) is put on the vertical scale.

Centre for the infinite return loss, i.e. $(1/125) \times \frac{1}{2\pi \times 10^{-3}}$

or (1·272, 0) is taken as the reference origin. Other centres (for other return losses) are set off from it.

The horizontal scale is calibrated in $G \times \frac{1}{2\pi \times 10^{-3}}$

to comply with vertical scale units.

$G = 125$ is on the scale at $(1/125) \times \frac{1}{2\pi \times 10^{-3}}$ or 1·272

which is the reference.

Other values of $G$ are set off from 1·272 in the reverse direction. For example:

$R = 120\Omega \quad \therefore G = (1/120) \quad \therefore G \times \frac{1}{2\pi \times 10^{-3}} = 1{\cdot}328$

$\therefore 1{\cdot}328 - 1{\cdot}272 = 0{\cdot}055.$

Hence 120 is marked off to the left of the reference origin by 0·055 of the 1in = 0·1 scale.

This chart can be used only in the particular case when return loss is required between an unknown impedance and $Z_o = 125\ \angle 0°\Omega$. Thus, in comparison with Smith charts its use is limited. But in telecommunication engineering characteristic impedances are sufficiently standardized to warrant the use of such a specialized chart.

The advantage of this chart over Smith charts lies in its simplicity and quickness of use.

**Acknowledgments**

The author wishes to express his thanks to Mr. N. Head for suggesting this method and to the G.E.C. Telephone Works for permission to publish this article.

# BBC High Power Experimental U.H.F. Television Transmissions

ON 11 November the BBC began a series of high power test transmissions on 654·25Mc/s to collect further data relating to the u.h.f. bands (Bands IV and V) which were allocated to television at the International Radio Conference at Atlantic City 1947, but have not so far been used for television broadcasting in this country.

The v.h.f. and u.h.f. bands allocated to sound and television broadcasting are as follows:—

| | | | |
|---|---|---|---|
| Band I | 41 to 68Mc/s | v.h.f. | used for BBC television |
| Band II | 87·5 to 100Mc/s | v.h.f. | part used for BBC sound programmes |
| Band III | 174 to 216Mc/s | v.h.f. | part used for I.T.A. television |
| Band IV | 470 to 585Mc/s | u.h.f. | |
| Band V | 610 to 960Mc/s | u.h.f. | |

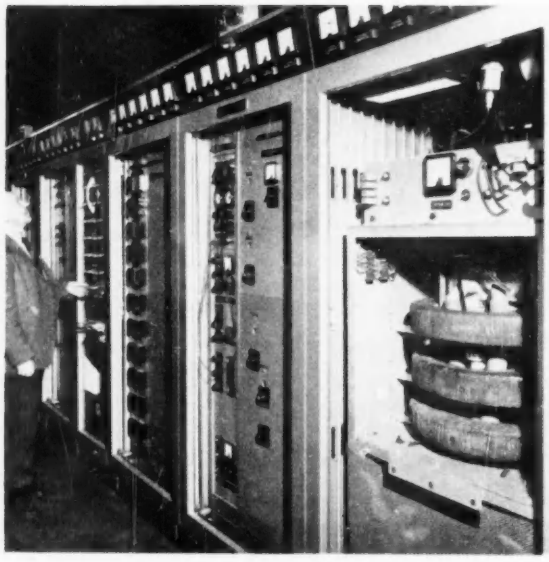


Fig. 1. The 10kW Band 2 vision transmitter showing the klystron output stage in the foreground

Following earlier laboratory work, the BBC embarked on its first series of u.h.f. propagation measurements in 1955. These were directed towards the investigation of propagation on frequencies between 479 and 960Mc/s over distances representing a normal service area, and over longer distances to obtain data necessary for the evaluation of co-channel interference. The initial tests were for the latter purpose and employed transmitters, modulated by square waves, manufactured for the BBC by Mullard Limited. The transmitters were installed at various television transmitting stations, the aerials being erected high up on the television masts. Regular field-strength measurements were made over long periods at various locations, some as far away as the Shetland Islands. These transmissions are still in progress

The long-distance tests were followed in 1956 by a series to determine propagation conditions within a typical service area using a transmitter at the Crystal Palace on 495 Mc/s, working into a Yagi aerial and radiating a peak power of 1kW over a fairly narrow beam when modulated with square waves; pulse modulation was also used for some of the tests. The bearing of the aerial, which was at a height of 440ft, was changed from time to time so that field-strengths could be measured over the whole circle from Crystal Palace. These measurements have been completed and the resulting information concerning field-strength contours and an assessment of shadow and echo effects are now being studied.

The information collected in this way was however insufficient to determine fully the best way of using Bands

Fig. 2. The elliptical waveguide at the front of the tower showing the concertina expansion couplings and the construction of the angle bends. The partly constructed cover is designed to protect the waveguide from mechanical damage

IV and V for television broadcasting, and at the request of the Television Advisory Committee the BBC decided earlier this year to embark on a more ambitious series of experiments using a high power transmitter and radiating full television signals, initially on 405 lines and later on 625 lines (C.C.I.R. standards). These tests have been planned by the BBC in co-operation with the Committee and the Radio Industry.

For this purpose the BBC has installed at the Crystal Palace a 10kW peak-white u.h.f. vision transmitter and a 2½kW carrier power sound transmitter manufactured by E.M.I. Electronics Ltd, the vision frequency being 654·25 Mc/s. The equipment which is shown in Fig. 1 is

low-power modulated on both sound and vision channels and employs Eimac 3K50000LF klystrons in both audio and video final stages. These klystrons use three external cavity resonators and operate as linear amplifiers with a power gain of approximately 100. They are driven by a modulated amplifier stage operating with a cathode modulated circuit. The output of the transmitters is combined in a circuit of the filter bridge type constructed in rectangular section waveguide. The combined output is then conveyed to the aerial by a 12in by 6in elliptical waveguide. Fig. 2 shows a view of the waveguide at the foot of the tower. The elliptical waveguide is made of 99·5 per cent aluminium in 12ft lengths. At the top of the television mast the waveguide is transformed into a 5in concentric feeder to take power to the four driving points of the helical aerial, the pole supporting the aerial being arranged to form the outer of the concentric feeder.

The helical aerial is made of ¼in diameter copper rod and comprises four bays mounted one above the other on the same vertical axis, each having a linear height of five wavelengths. Each bay (Fig. 3) is fed at the centre, the helix being wound from the centre point of the bay in opposing directions to cancel the vertical component of radiation. In the four bays there is a total of 48 turns, each turn being approximately two wavelengths long. The aerial is mounted at the summit of the Crystal Palace tower, the top of the 6½in diameter pole supporting the aerial being 707ft above the ground, while the centre line of the aerial is 691ft above the ground. The aerial has a power gain of 20 and after allowing for losses in the feeder and waveguide system, the effective radiated power of the vision signal is of the order of 125kW peak-white in the horizontal plane. The complete helical aerial prior to erection is seen in Fig. 4. Provision is made for de-icing the aerial by electrical heating.

The Band V transmitter is in operation for several hours a day radiating pictures on the 405-line standard. The pictures are the same as those radiated by the Band I transmitter installed in the same building. Later on, pictures on 625 lines will be produced at Lime Grove from flying spot telecine equipment supplied by Cinema-Television Ltd, and sent over a specially equipped coaxial cable to the Crystal Palace.

The tests on 405 lines will continue until about March 1958, when there will be an interval for the transmitter to be adjusted to radiate on 625 lines. A second series of tests will then begin and will continue for a period not yet decided. For these latter tests, the programme will usually be different from that being radiated by the Band I transmitter, but at certain times duplicate copies of films scanned on the two systems will be radiated by the two transmitters simultaneously.

The BBC, the Radio Industry, the Post Office, the D.S.I.R. and the I.T.A. are organizing comprehensive studies of the received pictures. A number of experimental receivers of various types will be used, some being representative of the designs that might be expected to become available to the public in the future. The BBC hopes that the information which will be gained from these tests will throw light on the problems to be considered by the Television Advisory Committee when preparing its recommendations for the future development of television in the United Kingdom, in particular on the problems which would be encountered were it decided to provide television service in the u.h.f. bands, and on the effects of a possible change of United Kingdom television standards for these bands to conform with the standards used on the continent. There is of course no intention of making any change in the 405-line standards used in Bands I and III.

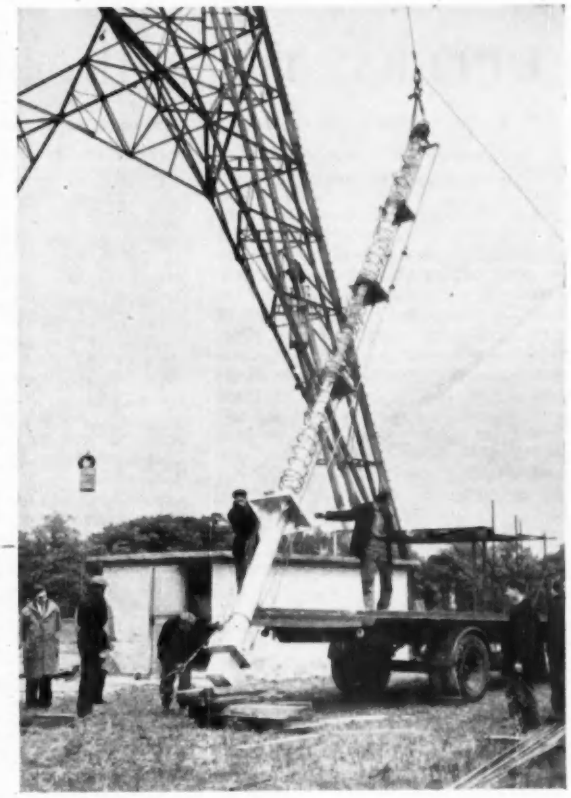


**Fig. 4. The four bay helical aerial about to be hoisted to the top of the existing BBC tower at Crystal Palace**

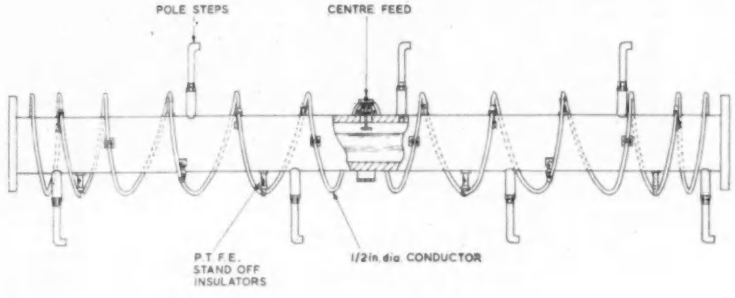



**Fig. 3. A single bay of the helical aerial**

# LETTERS TO THE EDITOR

*(We do not hold ourselves responsible for the opinions of our correspondents)*

### The Schmitt Trigger Circuit

DEAR SIR,—A useful modification to the 'Schmitt Trigger Circuit' enables the realization of a square wave generator using emitter coupled junction transistors. In the circuit of Fig. 1 the regenerative switching action is made to occur by suitably biasing $X_1$. If $X_1$ is initially conducting, $X_2$ is cut off. Connecting the capacitor to the base of $X_1$ turns $X_1$ off and $X_2$ on. The capacitor then charges up via $R_1$ and $R_2$ and turns $X_1$ on again and $X_2$ off. Since base current now flows, the capacitor discharges (effectively via $R_1$ and $\alpha CB$ $R_E$) and the collector voltage of $X_1$ rises, turning $X_2$ on and $X_1$ off once more.

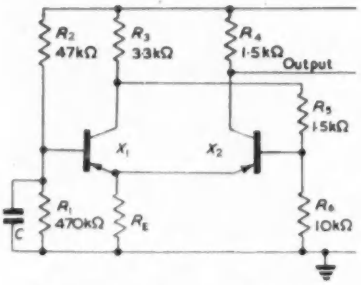



**Fig. 1. The modified Schmitt trigger circuit**

A straightforward linear analysis enables suitable component values to be chosen—the values given below are typical.

Compared with normal multivibrator circuits, this device has the advantage of a relatively free terminal at the collector of $X_2$. That is, the performance is relatively independent of the value of $R_L$. The output at the collector is a square wave with transition times limited only by the high frequency effects in the transistors themselves.

The repetition frequency depends upon the value of $C$ and operation is satisfactory up to about 10kc/s. Because of the high values of $R_1$ and $R_2$ the circuit is inherently unsuitable for high temperature operation.

Yours faithfully,

A. G. KLEIN

Department of Electrical Engineering,
University of Melbourne.

### Calibration of Vibration Pick-ups

DEAR SIR,—Mr. Foster's article which appeared in the October 1957 issue does not make reference to the upper frequency limit or the accuracy attainable by the methods described for calibration. It is thought that the frequency limit for these methods is 600c/s.

There is a further method which is often regarded as the most accurate for the calibration of pick-ups especially at high frequencies. This method involves the use of a Michelson Interferometer. If one mirror is fixed and the other mirror attached to the vibrating system[1], it can be shown that the fringe pattern vanishes at certain well defined amplitudes of vibration[2].

This method has now been in use in our laboratories for two years and has shown itself to be consistent and reliable, with an accuracy of better than 5 per cent for frequencies up to 10kc/s.

Yours faithfully,

J. G. HAYNES.

Environments Division,
E.M.I. Electronics Ltd.

**REFERENCES**


1. DAVIES, S. M. Calibration of Vibration Pick-ups at High Frequencies using a Michelson Interferometer. *Nature*, *178*, 161, (1956).
2. OSTBERG. *J. Opt. Soc. America* (1932).


### The author replies:

DEAR SIR,—With reference to Mr. J. S. Haynes' letter and his first query concerning the upper frequency limits of the methods described, I would like to point out that any frequency limitation is created not so much by the method, as by the vibration source and the pick-up under test. The limitation created by the method is one of amplitude, and is, of course, the minimum amplitude which can be measured with reliability. We can, for instance, measure an amplitude of ± 0·00025in in comfort by means of Fopple's triangle and even with an early type of moving-coil vibration generator such an amplitude is well within its range at 1kc/s. The theoretical maximum frequency for either the methods with unaided present day vibration equipment would be about 1·4kc/s.

It is possible, however, to extend this range very considerably by fitting resonant reeds to the vibration generator and an upper limit of 10kc/s can be reached by this means with ease and accuracy. It is of course necessary to use a very light moving-coil vibration generator with a light load such as a barium titanate pick-up.

Using synchronized stroboflash methods the normal commercial synchroflash is rated at about 500c/s maximum frequency, but even these have been used with special triggering circuits up to 1kc/s. The reflected light beam and strain gauge methods can also be used at frequencies well into the kc/s region.

The interference fringe method can be extended, by using an image convertor tube in place of the standard synchroflash lamp, and by this means its theoretical limit of frequency is set only by the decay time of the fluorescent screen. Unfortunately, at the moment I cannot quote any figures in this respect, but it seems likely that it is a matter of many megacycles per second.

Regarding the second point in Mr. Haynes' letter, the article was not intended to be comprehensive and many alternative methods have been omitted. The Michelson Interferometer is of course an excellent method of making static measurements, but for vibration measurements its accuracy, in practice, is somewhat open to doubt. This is due to the fact that the interferometer uses four reflecting or refracting mediums and if one or more of these mediums is subjected to vibration transmitted through the mounts serious, though not obvious, errors occur. Otherwise the method is very good.

Yours faithfully,

K. C. FOSTER,

Billericay, Essex.

## PUBLICATIONS RECEIVED

**THE BRITISH COUNCIL ANNUAL REPORT** 1956-57 states that widespread attention has been secured overseas by the opening of the first full-scale nuclear power station at Calder Hall. Such publicity needs to be supported by a sustained flow of information, it adds, and an increasing proportion of the Council's work consists in helping to disseminate knowledge of British scientific achievement and serving as a link between British experts and professional bodies and their opposite numbers overseas. In the last five years the Council has assisted some 7 000 visitors in the sciences, many of whom wished to survey instruments and equipment designed and built in Britain. The British Council, 65 Davies Street, London, W.1.

**'WIRELESS WORLD' DIARY** 1958 published by T. J. & J. Smith Ltd., in conjunction with 'Wireless World.' There are eighty pages of reference material plus the usual diary pages of a week to an opening. The diary is now in its 40th year of publication and the reference section includes base connexions for 700 current valves, design data, addresses of radio organizations in this country and abroad, licence regulations, etc. Price 6s 3d (Leather), 4s 6d (Rexine). Dorset House, Stamford Street, London, S.E.1.

**COMPUTERS** is the title of a new monthly by The Bureau of Technical Information, 38 bibliographical bulletin on the subject produced Farringdon Street, London, E.C.4. The Bulletin, published on the first of each month, will provide a complete record of everything published in this country and overseas on computers, fully annotated with all bibliographical details. The annual subscription is £6 6s.

**RECEIVING AERIAL SYSTEMS** by I. A. Davidson describes some of the technical problems associated with aerials particularly as they apply to domestic installations. It is divided into four parts. The first gives an outline of the subject in general terms; the second is concerned with particular types of aerials; the method of choosing the correct aerial for a given site is also explained; and finally there is a short description of the method of making aerial measurements as an illustration of the work that goes on behind the scenes when manufacturers give technical data on their products. Heywood & Co. Ltd. Ingersoll House, 9 Kingsway, London, W.C.2. Price 21s.

**RADIO VALVE DATA.** The latest edition of this reference book is over 25 per cent larger than the previous edition. It contains full operating data on over 2 500 types of British and American radio valves, 37 transistors, and 300 cathode-ray tubes. An index enables any valve to be found immediately in the tables, while the full list of equivalents, a new feature introduced in the fourth edition, has been retained and enlarged. Iliffe and Sons Ltd. Dorset House, Stamford Street, London, S.E.1. Price 4s. 6d.

**MAN AND AUTOMATION** by L. Landon Goodman is divided into two parts; technical aspects, and social economic, and other aspects. Under the first heading will be found sections on the applications of automation not only in engineering but also in industry generally. The human implications of automation are also discussed. Penguin Books Ltd, Harmondsworth, Middlesex. Price 3s. 6d.

# Short News Items

**Marconi Instruments** recently held a private exhibition at St. Albans of specialized test equipment for multi-channel links. The main exhibits comprised u.h.f. Test Set OA 1248, which provides comprehensive testing facilities for radio link equipment in the 1 700 to 2 300Mc/s band; White Noise Test Set OA 1249, used for the measurement of noise and intermodulation distortion in multi-channel telephony equipment; and Derivative Test Equipment OA 1259. The latter consists essentially of a sweep generator and a cathode-ray tube display unit, and has been designed primarily to enable the linearity controls of Marconi HM40 and HM60 Modern Racks to be adjusted for best performance. The applicability of these test instruments to the exact needs of link equipment is the result of close collaboration between the design engineers of Marconi Instruments and of the Communications Division of Marconi's Wireless Telegraph Co.

**BBC's Crystal Palace Television Tower.** An unusual test was made on the BBC's new 709ft tower on 20 November. As part of an investigation into the aerodynamic behaviour of the tower and to check the theoretical design calculations a battery of ten rockets were mounted on the tower at a height of 625ft above ground level and fired in sequence at predetermined intervals by remote control. The rockets were not detached from the tower when fired, but held fixed, and each exerted a thrust of half a ton. The movement of the tower produced by the reaction was recorded on electronic equipment in a mobile laboratory on the ground. It was the first time that this form of test has been made on a high tower in this country, and it is hoped that the results will add considerably to present knowledge of the behaviour of structures of this type in steady winds of relatively light force. The BBC's main contractors for the Crystal Palace tower, British Insulated Callender's Construction Co Ltd, placed the test in charge of Dr. A. R. Flint who conducted it in collaboration with the National Physical Laboratory and the Royal Aircraft Establishment.

**The Instruments, Electronics and Automation Exhibition,** to be held at Olympia in April, will be almost one third larger in floor area than the 1957 exhibition. With more than 60 new exhibitors, the British Section is completely sold out, and the organizers have a waiting list for space. At a special Exhibitors' Meeting, held at the close of the 1957 exhibition, it was decided that the 1958 I.E.A. Exhibition should become international, and already in the Overseas Section of the exhibition stand space has been booked for exhibitors from Belgium, Denmark, France, Germany, Holland, Sweden, Switzerland and the U.S.A. In addition to the trade associations who sponsored the 1957 I.E.A. Exhibition—The British Electrical and Allied Manufacturers' Association, The British Industrial Measuring and Control Apparatus Manufacturers' Association, The British Lampblown Scientific Glassware Manufacturers' Association, The Drawing Office Material Manufacturers' and Dealers' Association, The Scientific Instrument Manufacturers' Association of Great Britain—the Radio Communication and Electronic Engineering Association has joined this impressive list in promoting the 1958 exhibition. I.E.A. 1958 will again be accompanied by a conference, taking place at Olympia at the same time as the exhibition itself. This year's conference will be international in character, and scientists, engineers and industrialists from many continental countries, Canada and the U.S.A. have already asked for details. The exhibition is again organized on behalf of the promoting trade associations by Industrial Exhibitions Ltd, 9 Argyll Street, London, W.1.

**The South East London Technical College,** Department of Electrical Engineering and Applied Physics is organizing a course of six lectures on Modern Electric Network Theory and Design, commencing on 22 January. The course is intended to give a survey and summary of the analysis of communication networks and of modern design methods. The fee is 10s. and further information may be obtained from the Head of the Department concerned at Lewisham Way, London, S.E.4.

**PLUTO,** the new research reactor which recently commenced operation at Harwell, is equipped with Ekco nuclear instrumentation. Ekco Electronics Ltd designed, installed and commissioned the complete nuclear instrumentation and control circuits for this latest-type heavy water moderated reactor. Ekco Electronics have made substantial contributions to the design principles of the safety system of PLUTO, with the aim of achieving the highest possible standard of safety and reliability. Current Ekco projects include the complete nuclear instrumentation of the Australian HIFAR reactor at Lucas Heights and the DMTR reactor now being commissioned at Dounreay, Scotland.

**Easco Electrical (Holdings) Ltd** have recently been awarded a contract by the London County Council for the manufacture and installation of twelve combined broadcast equipments and staff communication systems for installation in twelve new Secondary Schools. This is believed to be one of the largest contracts placed for this type of equipment.

**The University of Birmingham** announces that a Graduate Course in Information Engineering will be repeated in the 1958-59 session. Applicants wishing to be considered for a D.S.I.R. grant for the session 1958-59, covering the fee of £81 and a maintenance allowance, should apply to the Electrical Engineering Department before 3 February. Copies of the syllabus of the course, or other information, may be obtained from The Supervisor of Graduate Courses, The Electrical Engineering Department, The University, Birmingham, 15.

**The Institute of Physics** has arranged a three-day conference on Nuclear Fuel Cycles to be held at The Institution of Civil Engineers, London, form 15-17 January. Full details may be obtained from The Institute of Physics, 47 Belgrave Square, London, W.1.

**The Second International Analogue Computation Meeting** will take place in Strasbourg in September 1958 under the patronage of the Association Internationale pour le Calcul Analogique. The sessions will take place from 1-9 September. On Sunday, 31 August, the partakers will be welcomed. An exhibition of analogue computation machines and equipment will be open from 30 August to 10 September. The programme of this meeting will cover the various Analogue Computation methods (differential analyzers, rheoelectrical analogies, network analysers, simulators, special calculators, etc.) and their applications to science and industry. Owing to the increasing tendency of associating analogue to digital methods, the Organizing Committee has decided to create a new group devoted to electronic digital computation, especially as regards its connexions with analogue computation. Those interested in further details of this meeting, or those intending to attend, or to particinate by submitting a paper, are requested to communicate with Monsieur F. H. Raymond, Secretaire Delegue General de l'Association Internationale pour le Calcul Analogique, 138 Boulevard de Verdun, Courbevoie (Seine) France. The representative of the Association in this country is Professor S. C. Redshaw of Birmingham University.

**The Nuffield Talking Book Library for the Blind** is appealing for volunteers to assist in the repair of the specially designed portable electric or battery gramophones used for the work. There are over 4 000 blind readers in Britain at present and only about 300 helpers, of which 100 are in Scotland; a large number of these are radio and television engineers. Help is urgently needed in London as well as numerous towns and areas in England. Further information may be obtained from Mr. D. Finlay-Maxwell, (Hon. Organizer of Voluntary Helpers), J. Gladstone & Co Ltd, Galashiels.

# BOOK REVIEWS

## The Services Textbook of Radio and the Services Textbook of Electrical Engineering. Volume 1: Electrical Fundamentals

**G. R. Noakes. 645 pp. 70 figs. Demy 8vo. Her Majesty's Stationery Office. 1957. Price 30s.**

TWO series of textbooks are being written for the use of Service technical personnel. The first series consists of seven volumes dealing with radio topics while the second is made up of five volumes on electrical engineering (Volume 3 in the Radio Series was reviewed in *Electronic Engineering* in August 1956). The book under review, which deals with the fundamentals of electrical science; is common to both series. The standard and scope of the majority of this volume is appropriate to the first year of a university course in electrical engineering. However, certain more advanced topics, such as harmonic-analysis, coupled-circuits and semi-conductors also receive space. In line with current practice in university courses and in Higher National teaching, the m.k.s. system of units is used throughout. One of the difficulties in working with m.k.s. units is that although the main electrical quantities such as volts, amperes, ohms, farads and henries are the same in m.k.s. units as in the everyday work, this does not apply to the units of mass and length. Thus conversion is usually needed to get the result of a calculation into British Units. This conversion often causes a little difficulty and it would have been helpful to have included a short appendix dealing with the conversion of quantities between the m.k.s. and the British system.

The book is written on two levels, the main text is intended for a reasonably able reader while those parts of it that may give difficulty to a beginner are "starred." The more mathematical proofs are given in the appendices, however, no particular high standard of mathematical ability is required to follow these proofs as only simple calculus is required.

The first chapter describes the mechanical units of work energy, etc. followed by a chapter describing the behaviour of charged bodies and of permanent magnets. Chapter III deals with the electric current and includes Ohms law, Kirchhoff's Law and the Wheatstone bridge. The remaining circuit theorems could well have been introduced at this stage instead of being left to much later in the book. Chapters on electrostatics, electromagnetism and electromagnetic induction are followed by a useful chapter on conventional magnetic materials (excluding ferrites). The rudiments of electro-chemistry and the action of primary and secondary cells are then explained. Chapter IX is on the ionization of gases and here the good standard of the earlier chapters is not maintained as the treatment is quite inadequate. No attempt is made to classify the various sorts of gaseous discharge and further, although naturally-occurring lightning is dealt with the glow-discharge is not mentioned.

The material so far discussed represents the first half of the book, and covers the basic electrical knowledge needed to understand the second half, which deals with electric motors and generators and a number of special topics. The understanding of the earlier work would be made easier if exercises had been included at the end of each chapter, and the space taken up by the special topics would perhaps have been better employed for this purpose. The text is illustrated by numerous simple sketches and, as is appropriate to a book on fundamentals, no attempt has been made to give illustrations of actual hardware.

For students who are taking a regular course of lectures the book provides a useful and readable introduction to the fundamentals of electrical engineering. However, the absence of numerical examples and the "two-level" approach make it somewhat less suitable for individual study particularly for examination purposes.

V. H. ATTREE

## Telecommunications

**By W. Fraser. 772 pp. 65 figs. Medium 8vo. Macdonald & Co. (Publishers) Ltd. 1957. Price 65s.**

THE standard aimed at is described by the author as that of an introductory text book for students reading for an Engineering Degree or who intend to take the examinations in Telecommunications of the Higher National Certificate, the City and Guilds of London Institute or the Institution of Electrical Engineers; the book is also claimed to be of value to "practising electrical engineers who wish to work in the field of electrical communications."

About half of the book is concerned with the basic theory of telecommunications, e.g. the theory of networks, circuit elements including transmission lines, valves, amplifiers, oscillators, modulators and demodulators, etc., and the theoretical aspects of the transmission of information; the remainder of the book is devoted to the elements of telecommunication systems proper, including telephony (manual and automatic); telegrahpy, including multi-channel voice-frequency telegraphy; facsimile; line-carrier, coaxial-cable and microwave radio links for multi-channel telephony and television; long-distance shortwave radio links; sound and television broadcasting.

This is an extremely wide field to attempt within the scope of a single volume and the author is to be congratulated on his courage in attempting it and the degree of success he has attained.

From the students point of view the book has many attractive features, the style is concise, clear and unencumbered by excessive detail, there is a good selection of worked examples and of questions from recent examination papers in Telecommunications set by London University and the Institution of Electrical Engineers; the references at the end of each chapter are well chosen, with a predominance of British publications which are likely to be more accessible to students than the American literature. Furthermore, the student is given in one volume the substance of several specialized text books and a good deal of material not otherwise available in text book form; apart from the question of practical convenience this is an economic advantage of special appeal to students, who are notoriously short of money.

From the view point of the practising engineer this book is perhaps less satisfactory since the wide range makes it impossible to more than touch on the practical engineerings aspects of telecommunication systems and there are some notable omissions. For example, microwave communication systems are now widely used in many countries for the transmission of television and multi-channel telephony over long distances; in the U.S.A. more than threequarters of the total television link mileage between cities and a quarter of the total trunk telephone circuit mileage are provided by this means. However, in *Telecommunications* some ten lines only (page 719, Chapter XXII) are devoted to such systems and it is said that "ultra-high frequencies are now used in long-distance transmission of television signals, and multi-channel telephony may be a future development." M.F. and v.h.f. broadcasting systems and v.h.f. mobile radio-communications systems also receive only a brief mention.

Summing up, it may be said that while this book provides a useful survey of the principles and theory of telecommunications well adapted to the needs of students, a wholly satisfactory text book on the practice of telecommunications has yet to be written; such a work would no doubt require the collaboration of several specialists in view of the wide scope of the subject, and a number of volumes.

A minor protest must be registered at the thickness of the present volume, it is more than three inches thick which is really too great for convenient handling and calls for the use of thinner paper or a sub-division into two volumes.

W. J. BRAY

## Technical Aspects of Sound: Volume II

**Edited by E. G. Richardson. 412 pp. 206 figs. Demy 8vo. D. van Nostrand Co. Inc., New York. Cleaver-Hume Press, London. 1957. Price 70s.**

THIS companion volume to the first part of the work deals with ultrasonics and underwater acoustics. The co-ordina-

tion of subject matter and uniformity of presentation are considerably better than in Part I. An errata slip corrects the few unavoidable errors.

Whilst there is much published literature on ultrasonics, this book devotes no fewer than 80 pages to the characteristics and design of transducers, in addition to 374 references to such applications. This section alone establishes the value of the work. Undoubtedly the most interesting sections are those contributed by Dean E. Meyer on air and gas bubbles in water, and the techniques and apparatus for the measurement of underwater sounds. These are paralleled by two further sections on absorbent systems for water-borne sounds, representing extensions of naval research in Germany during the war. Dr. Richardson adds the results of investigations into propellor noises and the various modes of cavitation in water.

Three chapters on aircraft propellor and jet noises by a team of eminent American experts complete the contents of this volume, thus bringing together a veritable mine of detailed and up to date information on this branch of acoustics. The 570 references cited ensure that the specialist in any branch of ultrasonics will have the means to amplify the contents of the 406 pages of this extremely well produced and readable compendium.

ALAN DOUGLAS

### Industrial Electronic Circuits

**By R. Kretzmann. 200 pp. 206 figs. Demy 8vo. Philips Technical Library, Holland. Cleaver Hume Press Ltd, London. 1957. Price 35s.**

THIS book deals with the circuits of industrial electronic apparatus. The functions of the various circuit elements are described and information is also supplied on the component values. Examples are given of photo-electric control devices, counting circuits for various purposes, stabilizing circuits, switching and control circuits, amplifiers and oscillators, rectifying circuits and motor controls.

### Der Transistor. Ein neues Verstärkerelement (The Transistor. A New Amplifier Element)

**By Joachim Dosse. 207 pp. 101 figs. Medium 8vo. (2nd revised and enlarged edition). R. Oldenbourg, München. 1957. DM.19·80.**

THIS is another instance where the rapid development of the subject necessitated the preparation of a second edition within not much more than one year after the publication of the first edition. This was reviewed in ELECTRONIC ENGINEERING in September 1956. The new editions shows not only an increase in the number of pages but also in size and the number of coloured plates has been increased from four to eight.

While the general explanation of the physical principles remains on the whole unchanged there is a more detailed discussion on the behaviour of the junction transistor in base connexion with sudden increase or decrease of emitter current as dependent on operation in the amplifier and saturation ranges of the volt/ampere characteristic. This is of particular importance for impulse amplifiers and relaxation connexions. A brief explanation of the diffusion of charge carriers is given.

The methods adopted for increasing the cut-off frequency are explained in greater detail and the diffusion transistor is described for which a cut-off frequency of more than 1 000Mc/s is predicted. The section on modified transistors is largely extended and particular attention is given to the avalanche transistor.

Perhaps the largest changes in comparison with the first edition will be found in the chapter dealing with the technical properties of the transistor. The treatment is somewhat more mathematical than before, particularly in the sections dealing with characteristic values and equivalent diagrams for amplifying weak signals and for noise. It is based partly on the use of equivalent diagrams which afford a good insight into the physical phenomena and partly on the more formal use of matrices in quadripole theory. A large number of numerical examples is given. Also the chapter on connexions and circuits is materially enlarged and brought up to date.

While in the first edition the main application consisted of hearing aids the transistors have meanwhile found a much larger field of application and are used e.g. in amplifiers for subscribers' apparatus, call and duplex telephony, channel amplifiers, impedance convertors, generators for carrier frequency and telegraphic purposes, studio amplifiers, series amplifiers for relays and measuring instruments and — last but not least — for computers.

The bibliography has been extended to cover the literature till January 1957 and contains now more than 630 references. The enlargements incorporated in this second edition greatly enhance its value, in particular for the designing engineer.

R. NEUMANN

### Industrial Television

**By H. A. McGhee. 120 pp. Demy 8vo. George Newnes Ltd. 1957. Price 15s.**

THE first section of this book deals with the practical aspects of governing the choice of cameras as well as the principles of pick-up devices. The author then covers the design of the associated control equipment, including synchronizing and blanking pulse generation, time-bases, supply circuits and remote control facilities. In the second part of the book, specific applications of such television systems are described and illustrated. Typical applications of television as a remote viewing aid in industry, including atomics and aviation, commerce, research and education, together with information on the capital and maintenance costs of closed circuit systems are described in the final chapter.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# ELECTRONIC EQUIPMENT

**A description, compiled from information supplied by the manufacturers, of new components, accessories and test instruments.**

## ELECTRONIC STETHOSCOPE

*(Illustrated below)*

**Airsonic Ltd, 14 Old Queen Street, London, S.W.1**

THE 'Soniscope' is an electronic stethoscope for carrying out investigations on machinery, pipe-lines, etc. The amplifier has a gain of 90dB with low distortion and can be tuned to any frequency between 25c/s and 20kc/s.

Operated from two miniature batteries within the robust metal instrument case, the overall dimensions are 4¼in by 3¼in by 1¾in. Two sets of stethoscopes can be connected simultaneously to one instrument, or one outlet connected to a meter, with or without loudspeaker. Several people can therefore study and interpret the signal at the same time. The Soniscope weighs 24oz.

Apart from its specific use as a stethoscope, the instrument will actuate most types of measuring instruments, graphers and tape recorders.

## SELECTOR UNIT

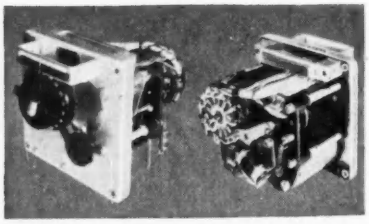
*(Illustrated above right)*

**The Plessey Co. Ltd. Vicarage Lane, Ilford, Essex**

A NEW light-weight selector unit, known as the type 9008, has been developed by the Plessey Company Limited in collaboration with the Royal Aircraft Establishment. This remotely controlled device has been designed for rotating a shaft to any one of twelve predetermined angular positions contained within one 320° turn, and locking it in the selected position.

Primary movement of the unit, which has been granted R.A.E. approval, is provided by an electric motor operated from a 48V d.c. supply which may vary between ±6V. A relay is used to control the operation of the motor and to reverse its rotation. Selection of the required preset position is provided by means of a single-pole 12-position switch at the remote operating position.

Each of the angular positions can be set individually without affecting the remaining eleven settings, and facilities are provided at the rear of the unit for



limiting the arc in which the twelve angular positions are contained. Accurate settings can be obtained by fine adjustments being made to the output or tuning shaft with a geared-down control knob.

The unit is capable of driving an external frictional load of 2¼lb. in and resets within nine minutes of arc on any single position. The average reset error obtained from all twelve positions is better than six minutes of arc. The output shaft, at the rear of the unit, extends through the front panel to carry a dial co-operating with a pointer. Another dial, which is visible through a circular window in the front panel, indicates which of the twelve positions is in use.

Overall dimensions of the unit, which has been designed for mounting in equipment protected against the free entry of dust, are approximately 4in by 4in by 4¼in depth. Weight is approximately 2¼lb.

## MULTI-RANGE METER

*(Illustrated below)*

**Avo Ltd, 92-96 Vauxhall Bridge Road, London, S.W.1**

TWO versions of this meter are available, the Multiminor model 1 for use in temperate climates, and the model 2 for use under adverse climatic conditions.

All components which could be moulded, have been made on precision moulding presses, the panclimatic version, using a recently developed moulding powder, which endows the finished product with a very high factor of electrical insulation, even when working under conditions of extreme humidity. Moreover, this new material resists the growth of fungus, an enemy of instruments used under humid conditions, and a very common cause of failure. The indicating movement has been constructed in a dust-proof casing, and all wiring is termite proof.

Range selection is by means of a rotary switch, there being only two connexion sockets for all measurements. The instrument has 19 ranges, a single scale being provided for current and voltage measurements and another for resistance measurements.

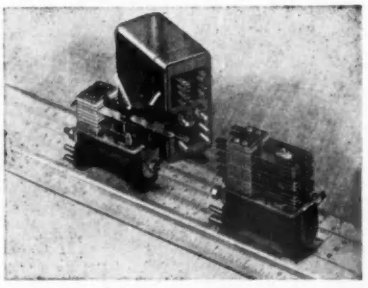
The voltage ranges cover from 0 to 1000V d.c. and a.c. and the current range 0 to 1A d.c. The lowest ranges are 0 to 100mV d.c., 0 to 10V a.c. and 0 to 100μA d.c. The d.c. sensitivity is 10kΩ/V and the a.c. sensitivity 1kΩ/V.

## SUB-MINIATURE RELAYS

*(Illustrated below)*

**D. Robinson & Co., 58 Oaks Avenue, Worcester Park, Surrey**

A MARK 2 version of the Hopwood-Paŋ type P3 sub-miniature relay is just announced. It can now have up to six changeover contacts for use in control



circuits, or two special changeover contacts with very low capacitances for such uses as 'send-receive' and crystal switching.

In addition it can now be used in temperatures up to 100°C; has a new shockproof knive edged armature mounting and as it has all tags and fixings at one end it can be mounted through a chassis (a piercing tool is available) or on a printed circuit.

The design target for the P3 was to provide as many of the features of the versatile "3000-type" as miniaturization allows and in consequence the P3 has buffered blades with twin contacts; excellent sensitivity and if required a residual adjusting screw by which the fall off point can be set to between 20 per cent and 60 per cent of the operate point.

Coils can be single or double wound; slugged and up to 9kΩ in value. Consumption can be as low as 100mW and typical contact ratings are 2A at 25V d.c. and 1A at 250V a.c.

The low capacitance version has low loss insulation and a capacitance between open contacts of under 1pF. The tag layout has been arranged to keep capacitances to ground low and constant.

## LIGHTWEIGHT SOLDERING IRON

*(Illustrated above)*

**Wolf Electric Tools Ltd, Pioneer Works, Hanger Lane, London, W.5**

OF entirely new design, the Wolf No. 92 lightweight soldering iron has been developed to meet the requirements of continuous small assembly and instrument work in the radio, television, electronic and allied industries.

The element is wound on a flat mica strip and folded with an interposing mica insulating piece. It is then encased in mica and enclosed within a rectangular section steel casing.

The dull, nickel plated copper bit is designed for easy replacement, being secured to the barrel by means of a special locking nut. A split moulded handle is used, with all terminals easily accessible. The cable and sleeve are securely clamped into position and an earth symbol permanently marked, conforms to various International regulations. Slots are provided in the chromium plated barrel to ensure that the temperature of the handle is maintained within comfortable limits.

The consumption of this iron is 25W and it is available for a wide range of voltage between 25 and 250V. The net weight of the iron is 3oz.

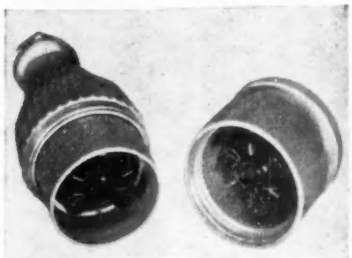
## PLUGS AND SOCKETS

*(Illustrated below)*

**Modern Acoustics Ltd, Manor Way, Boreham Wood, Hertfordshire**

THIS new range, which meets the stringent electrical and mechanical requirements of the latest electrical equipment, will be manufactured in the United Kingdom under licence from Tuchel Kontakt, Germany. All world-marketing rights outside Europe for the patented Tuchel design have been assigned by the Plessey Company Limited to Modern Acoustics Limited.

Basically, the contact consists of a series of tubes of decreasing diameters, opened longitudinally with two or more transverse slits, assembled one within the other. In operation, the bevelled contact blade is inserted into the first split cylindrical spring bank and as the blade is thicker than the gap, the spring assembly is forced apart and each of the three springs grip the blade pincer fashion. As the blade is introduced, the front edges of the spring assembly rub against it cutting through existing dirt or oxide film. This process is repeated through the second and third banks respectively, until the contact blade is fully inserted. An interesting feature is that the spring banks are not rigidly secured, but float in the connector assembly. This floating action ensures that the pressure exerted by the individual springs upon each side of the contact blade is always balanced. Other important features of this range of plugs and sockets are: a multiple number of independent contact points for each pole, low contact resistance with large contact area, unaffected by vibration, effective in a wide range of temperature, plus simple engagement. The variety of plugs and sockets available ranges from small ¼in diameter units, 36 poles per unit, each carrying 60A at 500V.



## MARKING MACHINES

*(Illustrated below)*

**Rejafix Ltd, 81-83 Fulham High Street, London, S.W.6**

THE diversity of components, their shapes, sizes and the various materials used in their manufacture, present a considerable marking or stamping problem in the electronic and radio component industry. The Rejafix combined marking and printing machine is so designed as to be able to mark direct on the surface of flat, round or irregular shaped components as well as articles having recessed surfaces.

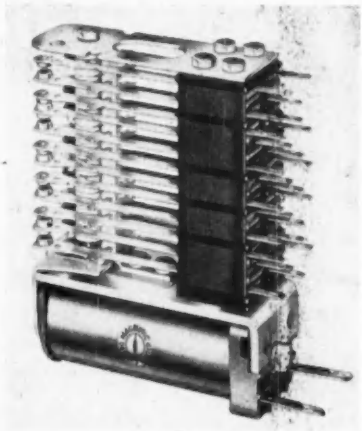
The Rejafix method is simple and it employs the use of positive conventional printing blocks. The printing block or type is automatically inked, and then brought into controlled light contact with the surface of a flat resilient transfer pad; thereby transferring a negative inked impression to the pad's surface.

The article to be marked is then rolled or presses on to this pad, and the inked impression is transferred to the surface of the article. The result is most efficient, and long continuous runs of marking can be carried out, giving the same quality of marking throughout the run.

On the hand-operated models up to 800 pieces per hour can be marked, while on the power-driven models it is up to 3 600 pieces according to the article.

For use in conjunction with their machines Rejafix Ltd supply a range of high quality marking inks in different grades to suit various materials such as glass, paper, cardboard, metal, rubber, wood, p.v.c., Bakelite, Perspex and many other kinds of plastics, as well as far marking on painted surfaces. A ceramic ink is also available for indelibly marking on glass and porcelain.

Illustrated is a 12 position turret model being used to stamp capacitor plates.



## D.C. RELAYS

*(Illustrated above)*

**Magnetic Devices Ltd, Exning Road, Newmarket, Suffolk**

THE series 285 relay is extremely compact and has been designed specifically to meet the requirements of the industrial, Electronics and automation fields.

It has a lifter comb and buffer block between the contact stacks and the high insulation properties of the relay are ensured by the encapsulating of the contact units, at their clamped ends.

The original design of lifter comb and buffer block allows for up to 10 pole changeover light duty contacts. Negligible contact bounce is a further feature of the series 285 relay.

With a 12750Ω coil and 2 pole changeover contact assembly the sensitivity is approximately 3mA. These relays are available with a wide range of coil resistances and contact assemblies.

## U.H.F. ATTENUATOR PADS

**Advance Components Ltd, Roebuck Road, Hainault, Ilford, Essex**

THE type A83 attenuators are coaxially pads with rod and disk type resistors in T networks. These pads are the same units as used in the turrent attenuator type A63. Five units are available in steps of 10dB and each unit is fitted with Plessey minor coaxial fittings so that they may be joined together in the same line.

These attenuators are capable of handling up to 0·5W of sine wave power. In sharply pulsed conditions their rating is limited by the peak voltage of the signal. The limit of the voltage is of the order of 100V for pulses of a few microseconds duration.

# Meetings this Month

## THE BRITISH COMPUTER SOCIETY

Date: 20 January. Time: 6.15 p.m.
Held at: York Hall, Caxton Hall, Westminster, London, S.W.1.
Lecture: The Physical Principles of Xerography.
By: N. Levin.

## THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: 29 January. Time: 6.30 p.m.
Held at: The London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.
Lecture: Ultra-High-Speed Oscillography.
By: I. Maddock.

**West Midlands Section**

Date: 8 January. Time: 7.15 p.m.
Held at: The Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.
Lecture: Instrumentation of Space Vehicles.
By: N. R. Nicoll.

**North Eastern Section**

Date: 8 January. Time: 6 p.m.
Held at: The Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road, Newcastle-upon-Tyne.
Lecture: The Earth Satellite Project.
By: P. H. Tanner.

**South Midlands Section**

Date: 31 January. Time: 7 p.m.
Held at: The Winter Gardens, Malvern.
Annual General Meeting, followed by Lecture: Digital Computers.
By: R. Deighton.

## BRITISH SOUND RECORDING ASSOCIATION

Date: 17 January. Time: 7.15 p.m.
Held at: The Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2.
Lecture: The Electrical Production of Music.
By: Alan Douglas.

## THE INSTITUTE OF NAVIGATION

Date: 17 January. Time: 5.15 p.m.
Held at: The Royal Geographical Society, Kensington Gore, London, S.W.7.
Lecture: The Influence of Atmospheric Conditions on Radar Performance.
By: J. R. Saxton.

## THE INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, will be held at the Institution commencing at 5.30 p.m.

**Ordinary Meeting**

Date: 9 January.
Lectures: The Development of Variable-Speed High-Power Drives for large Wind Tunnels and A Variable-Frequency Power Installation for Large Wind-Tunnel Drives.
By: P. McKearney, L. S. Drake and E. G. Mallalieu.
Speed Control of Large Wind Tunnels with particular reference to the R.A.E. 8ft by 8ft High-Speed Wind Tunnel.
By: L. S. Drake, J. H. Fox and G. H. A. Gunnell.
Data-Setting and Electrical Control Gear for the Flexible Nozzle and Diffuser of a High-Speed Wind Tunnel.
By: C. R. Dunham.

**Measurement and Control Section**

Date: 21 January.
Lecture: The Effect of Modern Industrial Requirements on Electrical Instrument Design.
By: G. F. Tagg.

**Radio and Telecommunication Section**

Date: 22 January.
Lecture: Special Problems of Broadcasting in Sweden.
By: E. Esping.
Date: 27 January.
Informal Evening: An Inquiry into the Specification of Transistors.
By: F. F. Roberts.
Date: 28 January. Time: 2.30 p.m.
Symposium: Long-Distance Propagation Above 30Mc/s.
(a) Ionospheric Forward Scatter Propagation. Time:5.30 p.m.
(b) Tropospheric Propagation Beyond the Horizon.

**East Midland Centre**

Date: 7 January. Time: 6.30 p.m.
Held at: The College of Arts and Crafts, Waverley Street, Nottingham.
Lecture: Earth Electrode Systems for Large Electric Stations.
By: J. H. Humphries.

**North-Eastern Centre**

Date: 13 January. Time: 6.15 p.m.
Held at: Neville Hall, Newcastle-on-Tyne.
Lecture: Earthing of Low- and Medium-Voltage Distribution Systems and Equipment.
By: F. Mather.
Date: 14 January. Time: 7 p.m.
Held at: Workington College of Further Education.
Repeat of above Lecture.

**North-Western Centre**

Date: 7 January. Time: 6.15 p.m.
Held at: The Engineers' Club, 17 Albert Square, Manchester.
Lectures: The Development of Variable-Speed High-Power Drives for Large Wind Tunnels and: A Variable-Frequency Power Installation for Large Wind-Tunnel Drives.
By: P. McKearney, L. S. Drake and E. G. Mallalieu.

**North-Western Measurement and Control Group**

Date: 21 January. Time: 6.15 p.m.
Held at: The Engineers' Club, 17 Albert Square, Manchester.
Lecture: Power System Protection, with particular reference to the Application of Junction Transistors to Distance Relays and: A Dual-Comparator Mho-Type Distance Relay Utilising Transistors.
By: C. Adamson and L. M. Wedepohl.

**North-Western Supply Group**

Date: 28 January. Time: 6.15 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: The Digital Computer Applied to the Design of Large Power Transformers.
By: W. A. Sharpley and J. V. Oldfield.

**North Lancashire Sub-centre**

Date: 6 January. Time: 7.15 p.m.
Held at: The North Western Electricity Board Demonstration Theatre, 19 Friargate, Preston.
Lecture: The BBC Sound Broadcasting Service on Very-High Frequencies.
By: E. W. Hayes and H. Page.

**Northern Ireland Centre**

Date: 13 January. Time: 7.30 p.m.
Held at: Sir William Whitla Hall, Queen's University, Belfast.
Lecture: Engineering Education in the Soviet Union.
By: P. E. Sleight and E. Giffen.

**North Scotland Sub-centre**

Date: 9 January. Time: 7 p.m.
Held at: Electrical Engineering Department, Queen's College, Dundee.
Lecture: The Remote and Automatic Control of Semi-Attended Broadcasting Transmitters.
By: R. T. B. Wynn and F. A. Peachy.
Date: 10 January. Time: 7.30 p.m.
Held at: Robert Gordon's Technical College, Aberdeen.
Repeat of above Lecture.

**South-East Scotland Sub-centre**

Date: 8 January. Time: 7 p.m.
Held at: The Carlton Hotel, North Bridge, Edinburgh.
Chairman's Address: Too Much and Too Little.
By: M. G. Say.
Date: 20 January. Time: 7 p.m.
Held at: The Carlton Hotel, North Bridge, Edinburgh.
Lecture: Some Aspects of Half-Wave Magnetic Amplifiers.
By: G. M. Ettinger.
Date: 21 January. Time: 7 p.m.
Held at: The Carlton Hotel, North Bridge, Edinburgh.
Informal lecture: The Importance of Research in Hearing and Seeing to the Future of Telecommunication Engineering.
By: E. C. Cherry.

**South Midland Radio and Measurement Group**

Date: 27 January. Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: Transistor Circuits and Applications.
By: A. G. Milnes. (To be read by G. W. E. Stark.)

**Rugby Sub-centre**

Date: 29 January. Time: 6.30 p.m.
Held at: Rugby College of Technology and Arts.
Lecture: Recent Developments in X-Ray and Electron Microscopy with Some Applications to Radio and Electronics.
By: C. W. Oatley and V. E. Cosslett.

**Southern Centre**

Date: 1 January. Time: 6.30 p.m.
Held at: C.E.A., Portsmouth.
Lecture: Cathodic Protection.
By: L. B. Hobgen, K. A. Spencer and P. W. Heselgrave.
Date: 8 January. Time: 6.30 p.m.
Held at: R.A.E. Technical College, Farnborough.
Lecture: Colour Television.
By: C. J. Stubbington.
Date: 15 January. Time: 6.30 p.m.
Held at: Brighton Technical College.
Lecture: The BBC Sound Broadcast Service on Very-High Frequencies.
Date: 24 January. Time: 6.30 p.m.
Held at: South Dorset Technical College, Weymouth.
Lecture: Gyroscopic Stabilizers.
By: H. Neal.

**Western Centre**

Date: 13 January. Time: 6 p.m.
Held at: Bristol University Engineering Laboratories.
Lecture: The BBC Sound Broadcasting Service on Very-High Frequencies.
By: E. W. Hayes and H. Page.

**Western Utilization Group**

Date: 27 January. Time: 6 p.m.
Held at: South Western Electricity Board, Bristol.
Informal Discussion on The 13th Edition of the I.E.E. Wiring Regulations.
Opened by: Forbes Jackson.

## THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Date: 6 January. Time: 5 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, London, W.C.2.
Lecture: The Introduction of Subscriber Trunk Dialling.
By: A. J. Thompson and N. Walker.
Date: 22 January. Time: 5 p.m.
Held at: The Conference Room, 4th Floor, Waterloo Bridge House, London, S.E.1.
Lecture: Subs. Line Concentrators—Their Development and Application.
By: A. J. Barker and G. M. Blair.

## THE TELEVISION SOCIETY

Date: 9 January. Time: 7 p.m.
Held at: The Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2.
Lecture: A French Portable Television Camera.
By: J. Polonsky.
Date: 23 January. Time: 7 p.m.
Held at: The Royal Institution, 21 Albemarle Street, London, W.1.
The Fleming Memorial Lecture: Crystal Valves.
By: T. R. Scott. (Admission by ticket only.)


## BINDING OF VOLUMES

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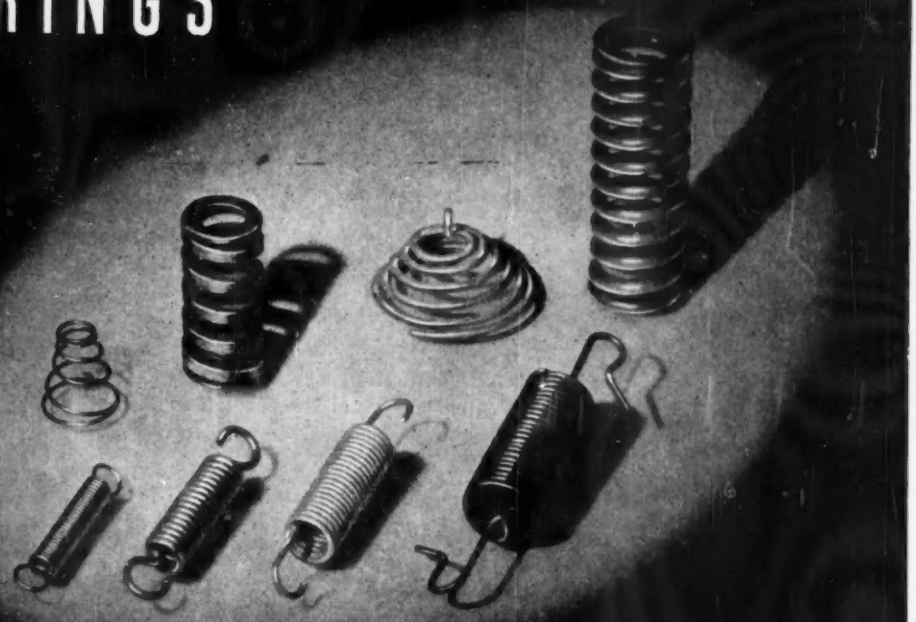

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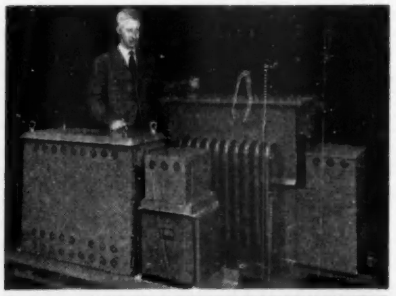
# MS SILICONE Dielectric materials

### SAFER ELECTRICAL TRANSFORMERS

The fire risk associated with oil-filled transformers is eliminated with silicone-insulated dry-type transformers. Units up to 3MVA, 15kV are in production.

Size and weight can also be cut, as can be seen here. The larger transformer on the right is oil-filled using conventional insulation. The one on the left (with the same rating) is silicone insulated and is 680 lb. lighter.

*By courtesy of Marconi's Wireless Telegraph Company Ltd.*



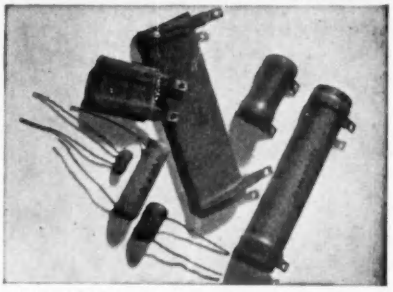
### DIELECTRIC COMPOUND

MS 4 compound is a non-melting, water-repellent paste which retains its grease-like consistency from —50°C to 200°C. It is highly resistant to oxidation and deterioration caused by corona discharge. Power factor is less than 0.001 up to 10 Mc/s; volume resistivity is more than $10^{12}$ ohm cm up to 200°C. Electric strength is more than 500 volts/mil at a 10 mil gap.

USES: Potting and sealing compound for electronic components, disconnectable plugs and sockets. Lubricant and protective agent for plastic and rubber cables, grommets and seals. Damping medium in gramophone pick-ups.

### SILICONE BASED CEMENTS

These cements are ideal for coating wire-wound resistors and similar components. Coatings are easily applied and processed and will withstand operation up to 250°C. They show excellent resistance to moisture.



### LIQUID DIELECTRICS

MS 200 fluids are dielectrics available in a range covering all degrees of viscosity. Their importance lies in their resistance to both heat and moisture. They are unique liquid dielectrics because their power factor is less than 0.0001 over all frequencies from 1 kc/s to 10Mc/s and all temperatures within the –35°C to 150°C range.

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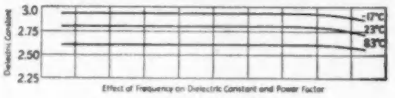
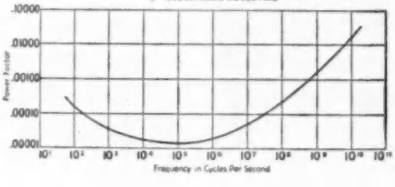

Effect of Frequency on Dielectric Constant and Power Factor of 1000 Centistoke MS 200 Fluid

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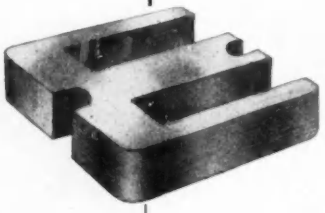

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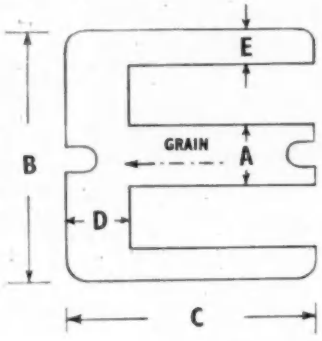


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| | | in. | in. | in. | in. | in. | in. | in.² | cm² |
| 258 | 532 | 0·004 | 3/16 | 3/4 | 3/4 | 3/16 | 3/32 | 0·070 | 0·45 |
| 224 | 521 | 0·004 | 1/4 | 1 | 1 | 1/4 | 1/8 | 0·125 | 0·807 |
| 225 | — | 0·004 | 3/8 | 1 1/2 | 1 1/2 | 3/8 | 3/16 | 0·281 | 1·815 |
| 225N | 522N | 0·004 | 3/8 | 1 1/2 | 1 1/2 | 3/8 | 3/16 | 0·281 | 1·815 |
| 226 | — | 0·004 | 1/2 | 2 | 2 | 1/2 | 1/4 | 0·500 | 3·23 |
| 226N | 523N | 0·004 | 1/2 | 2 | 2 | 1/2 | 1/4 | 0·500 | 3·23 |
| 227 | — | 0·004 | 5/8 | 2 1/2 | 2 1/2 | 5/8 | 5/16 | 0·781 | 5·04 |
| 227N | 524N | 0·004 | 5/8 | 2 1/2 | 2 1/2 | 5/8 | 5/16 | 0·781 | 5·04 |
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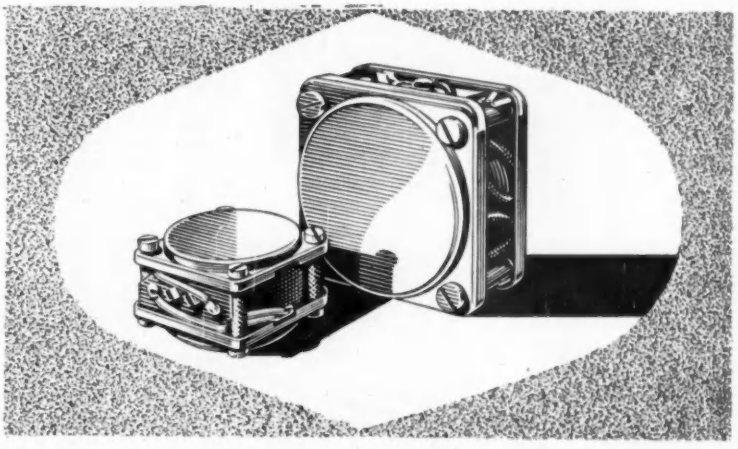

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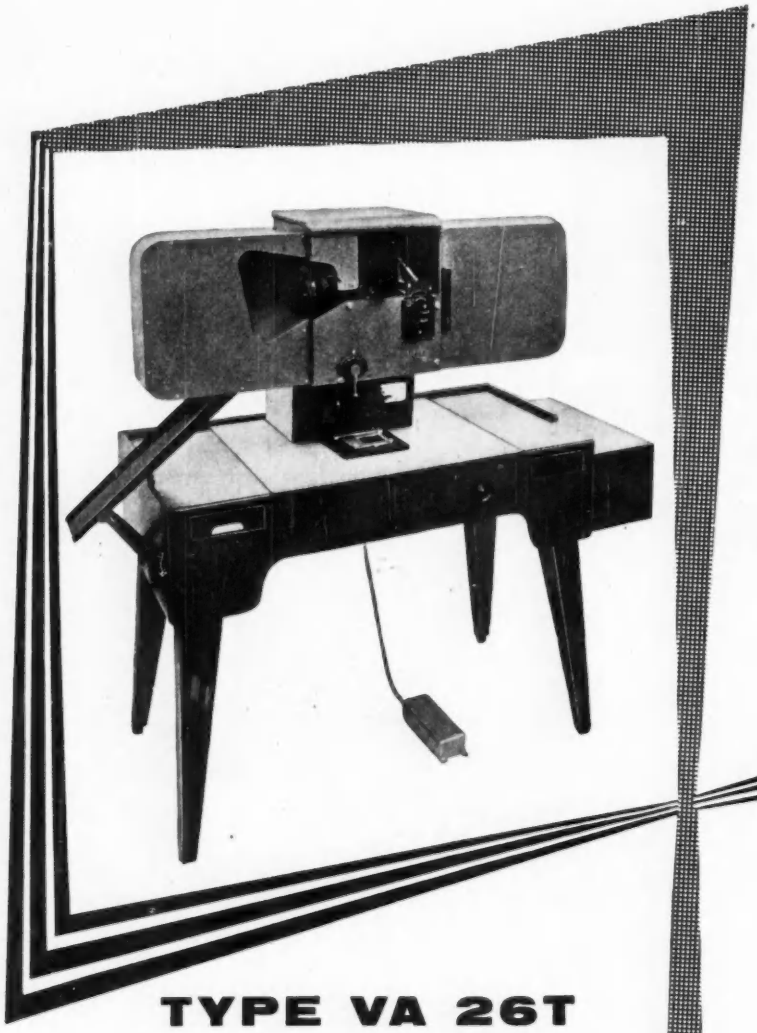
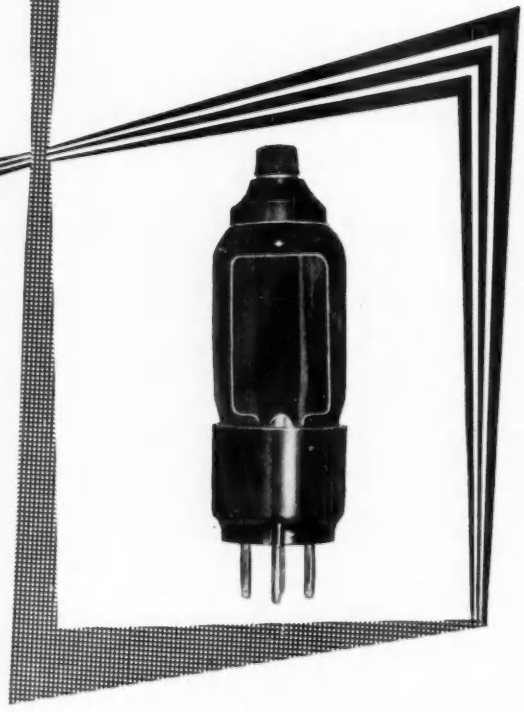


# PHOTO CELLS IN ACTION



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The unit illustrated costs less than £250 and operates in the 100-156 Mc/s band on a channel separation of 100, 50 or 25 Kc/s. The transmitter power is 25 watts, and the receiver has a sensitivity of 1 microvolt. Simplex or duplex operation is provided. Up to 5 adjacent channels may be used. Supply: 100-250 volts, 50 cycles, A.C. Height: approx. 26 in., supplied in cabinet or for standard rack mounting, with direct or remote control.

*We shall be happy to send you more detailed technical data.*

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Actual size

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| Vh–k(pk) | = ±250V max. |
| Val+a3 | = 350V min. |
| Sx | $= \frac{95}{Va3}$ mm/V |
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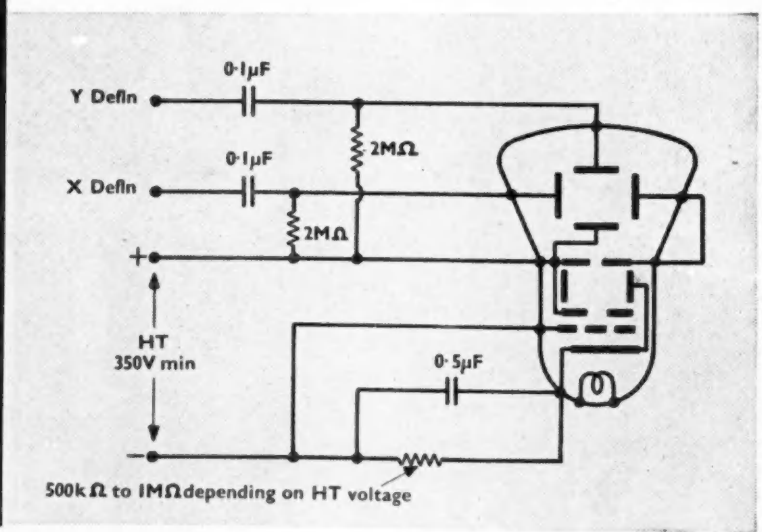


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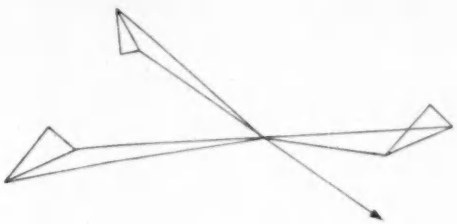

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" I know it's a bind
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deciding on a rating,
sending out the specifications,
getting quotations
and then finding it can't be delivered
until it's too late.
But get your brain washed of that mentality my lad.
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with dimensions, characteristics, price, fixing centres—
the whole jolly lot !
And they say they give 'off the shelf delivery' too.
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**input** 200/250 volts, 50 cycles
**polarity** positive or negative grounded available
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against mains variations: +5%,—10%. Better than 1%

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**output** 50kV at ½mA
**input** 200/250 volts
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against mains variation: +5%,—10%. Better than 1%
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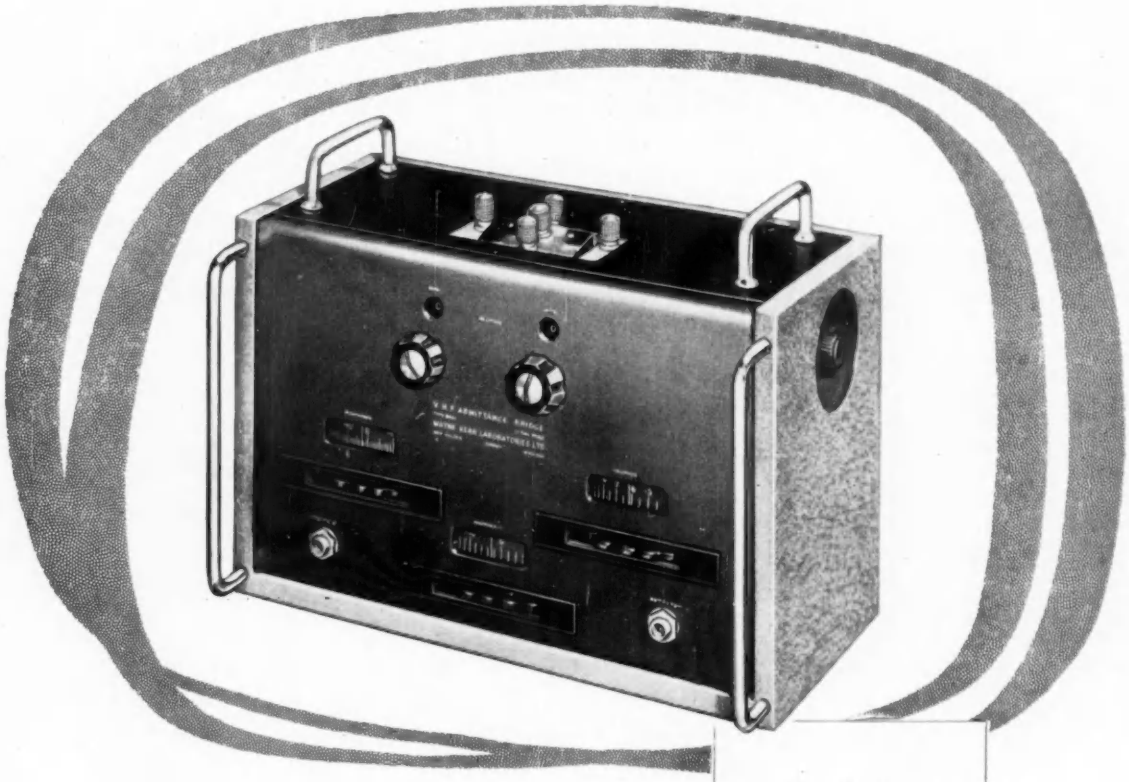

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Specially designed source and detector are available.

**Specification:**

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Accuracy: ±2%, ±0.5 pF

Conductance range:
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Accuracy: ±2%, ±0.1 mmho

Price: £165

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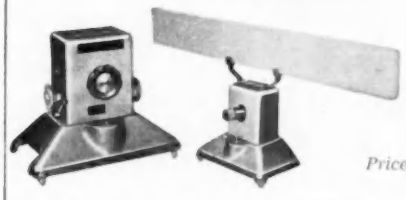

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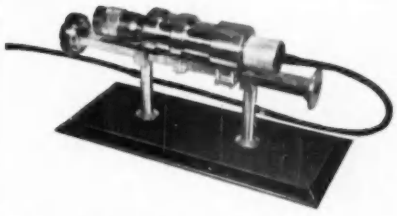
*Price £300 net ex works.*



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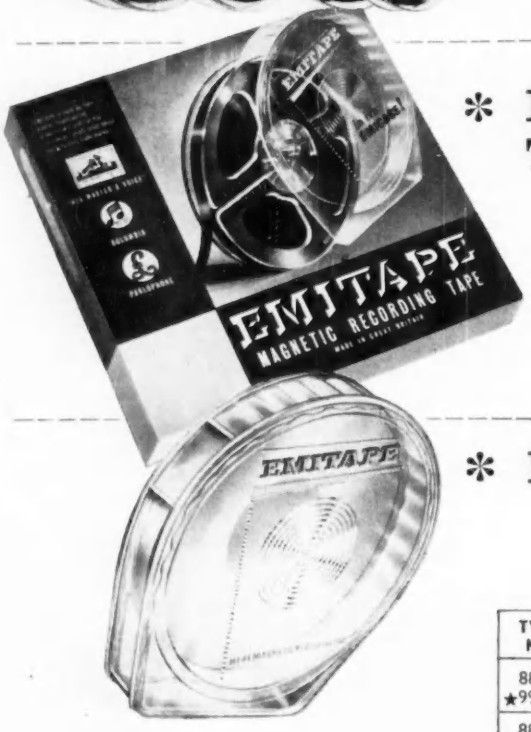


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solves storage problems
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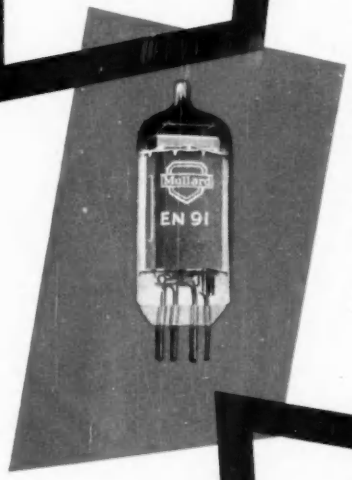


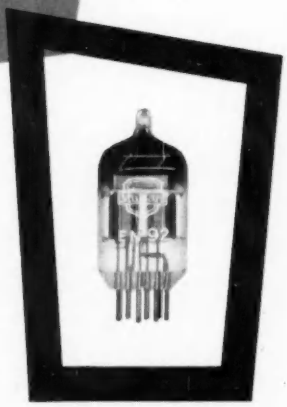

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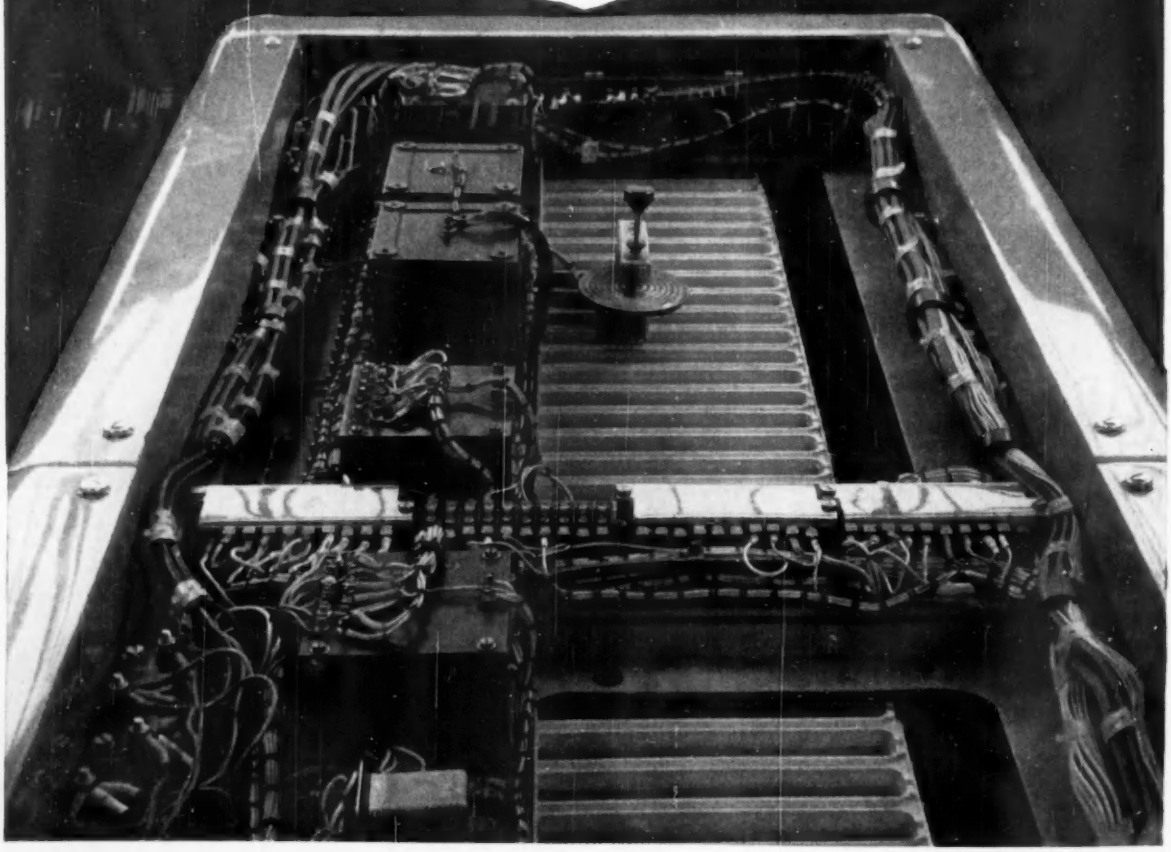

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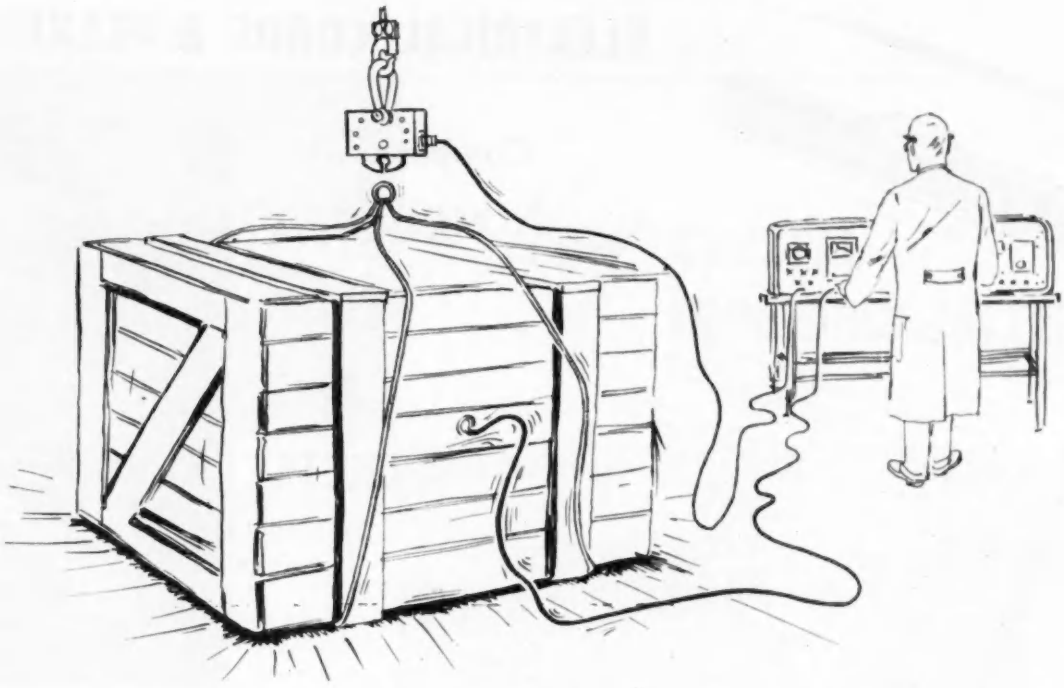

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It has been established that all packages suffer greater or lesser degrees of shock and vibration whilst stacking or whilst in transit by road, rail, sea or air. Here at last is a simple set of equipment enabling your Packaging Department to anticipate them and quickly design packaging to suit each product and ensure safe carriage for *all* your goods.

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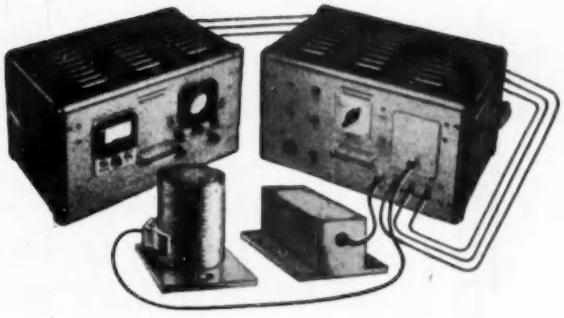

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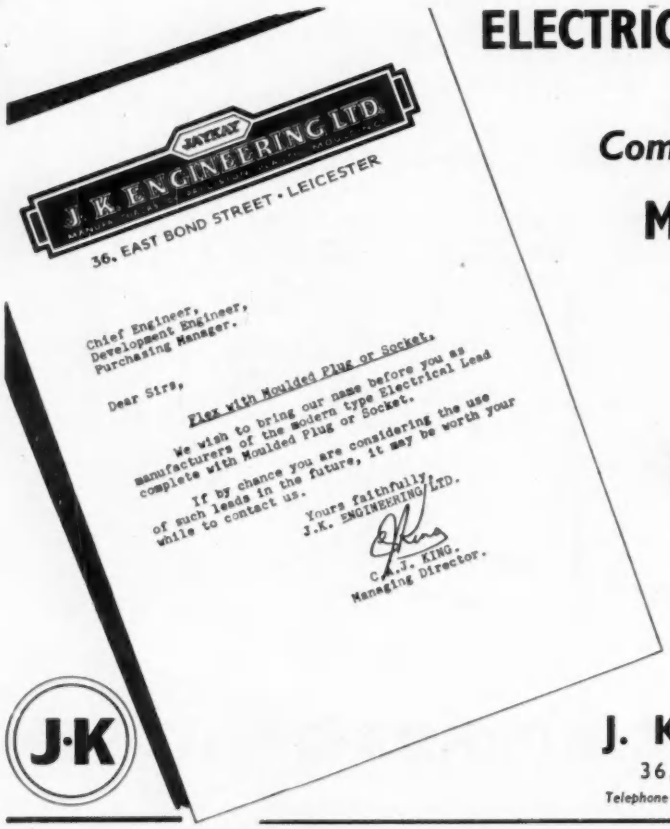
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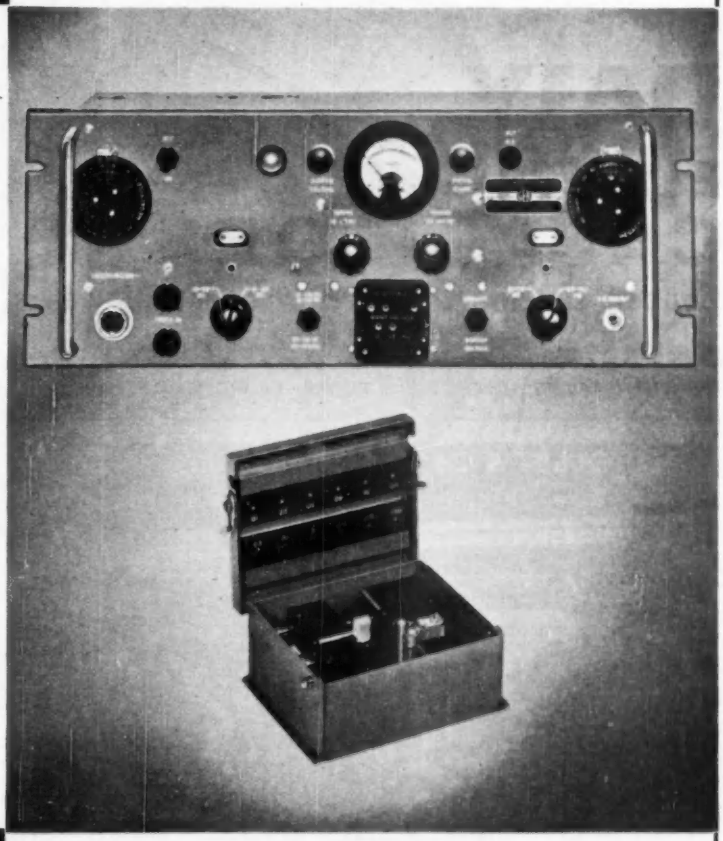

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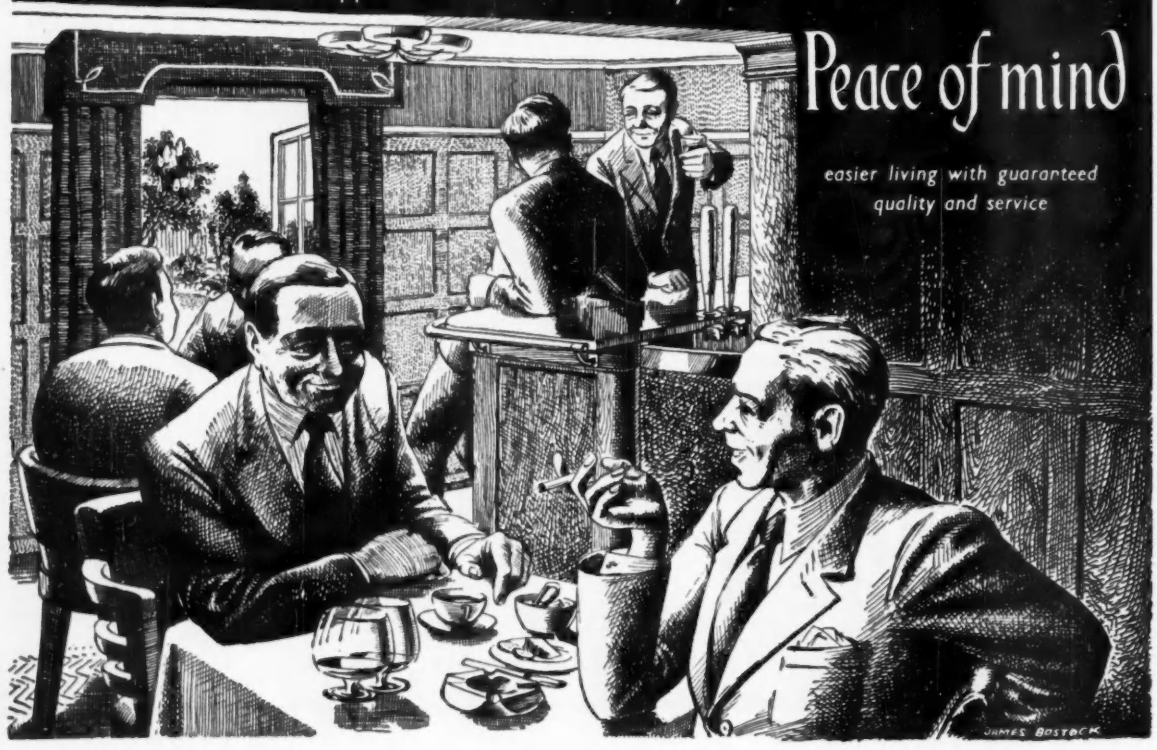

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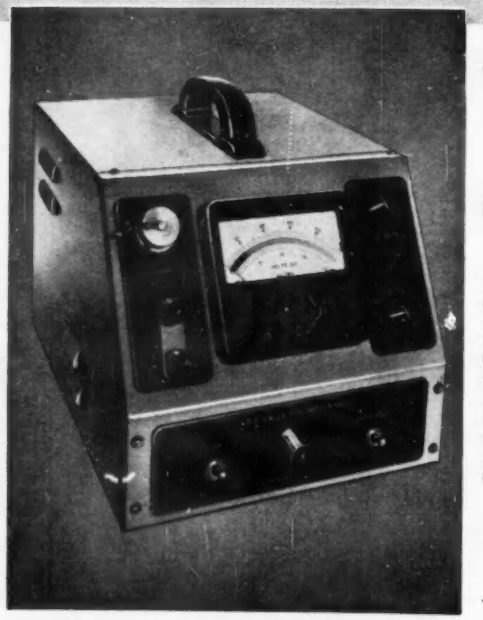

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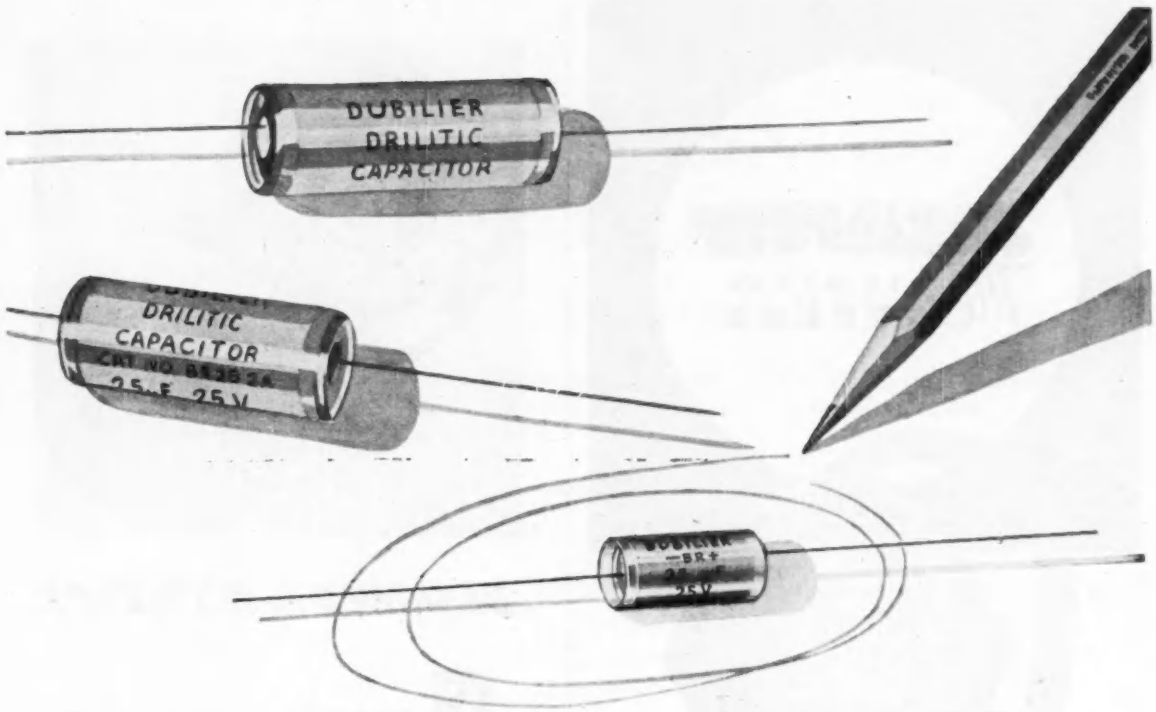


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| 10 | 25 | $\frac{7}{16}$ | $\frac{3}{4}$ |
| 25 | 25 | $\frac{7}{16}$ | $\frac{3}{4}$ |
| 5 | 50 | $\frac{7}{16}$ | $\frac{3}{4}$ |
| 10 | 50 | $\frac{7}{16}$ | $\frac{3}{4}$ |
| 4 | 100 | $\frac{7}{16}$ | $\frac{3}{4}$ |
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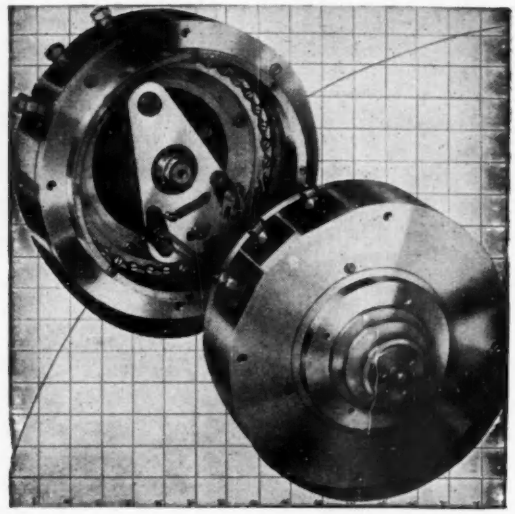

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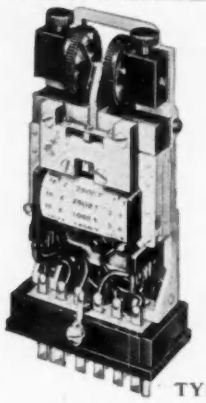

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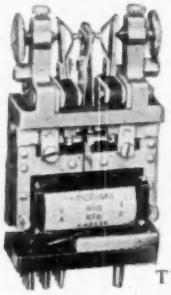

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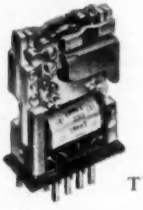

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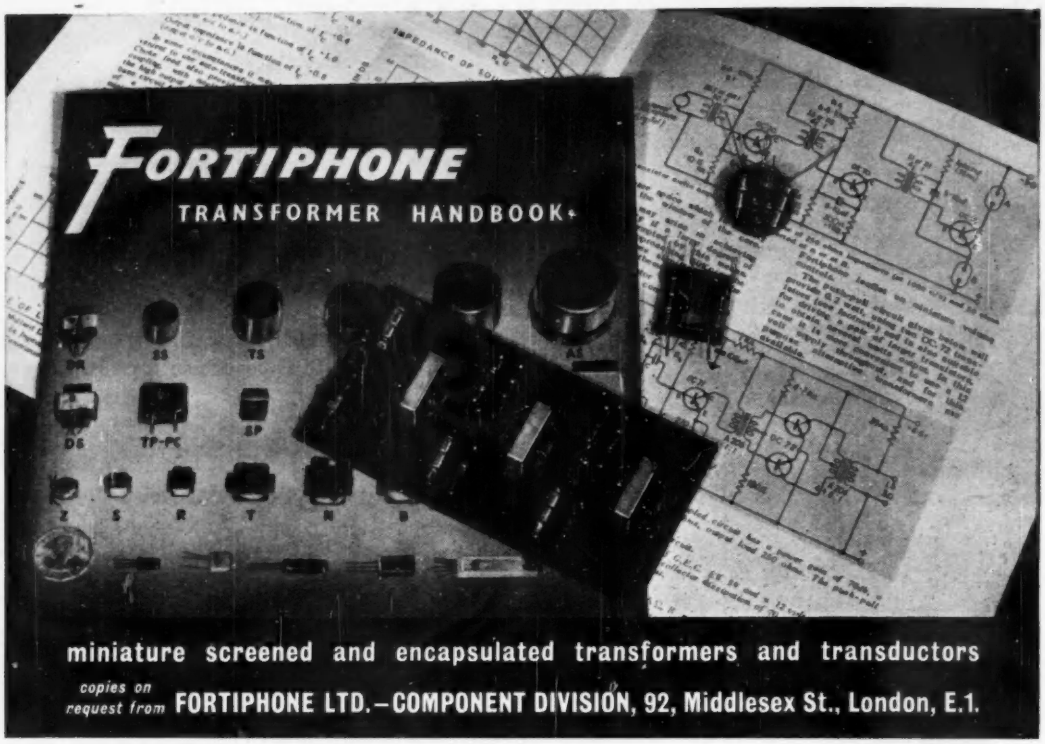


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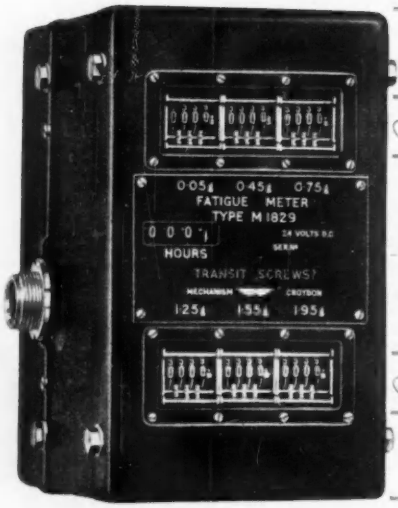


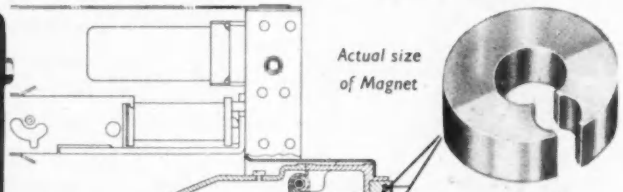

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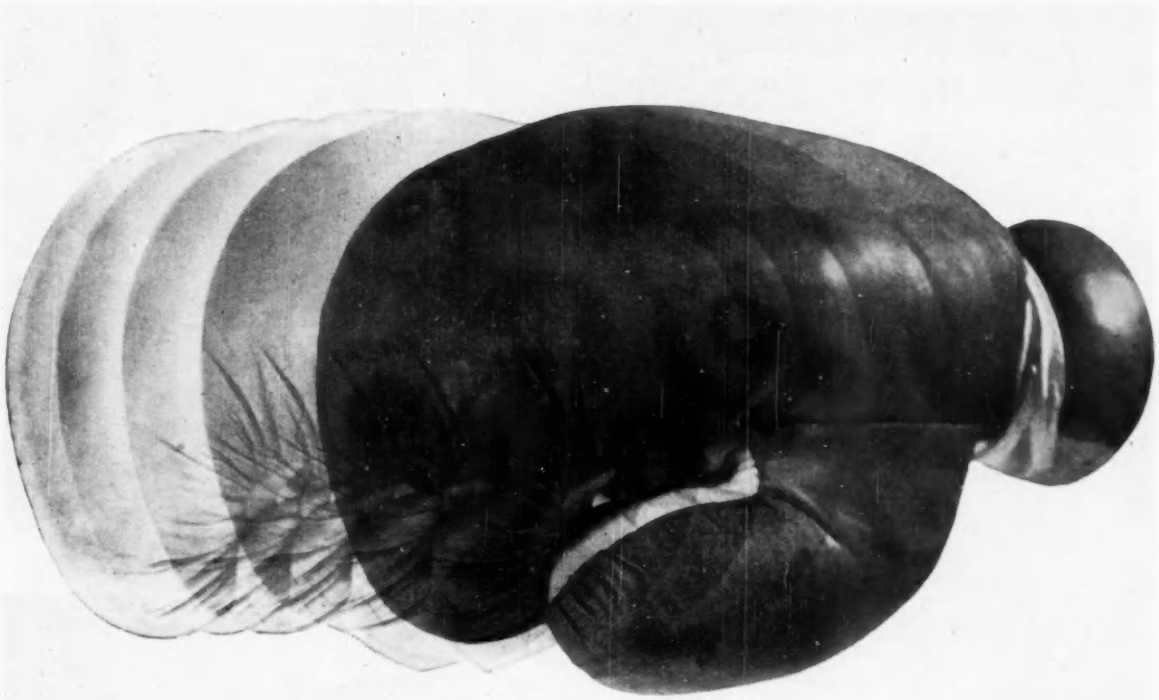
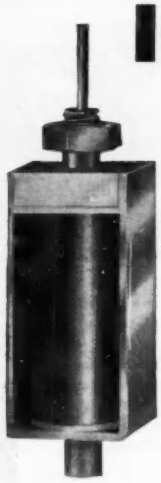


# 1000 times a minute!



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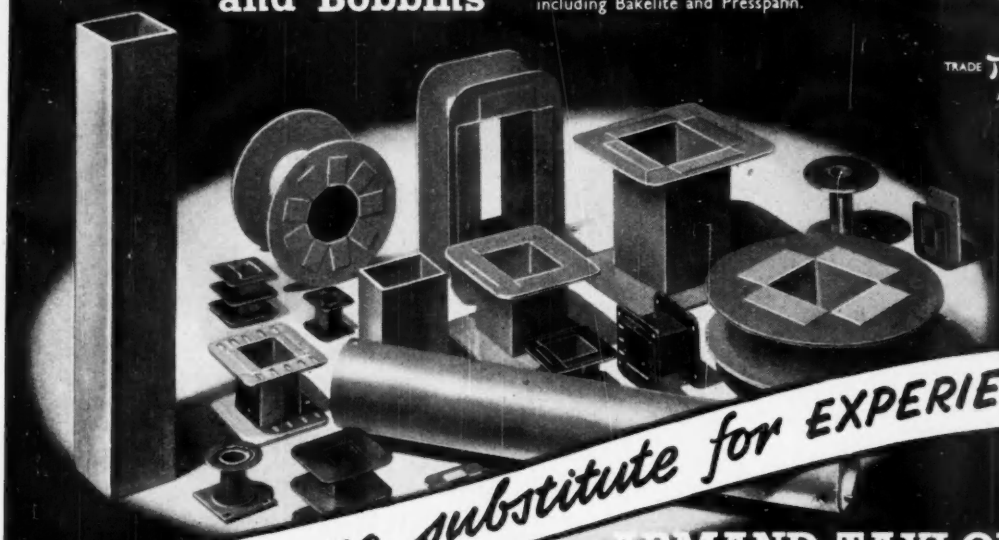

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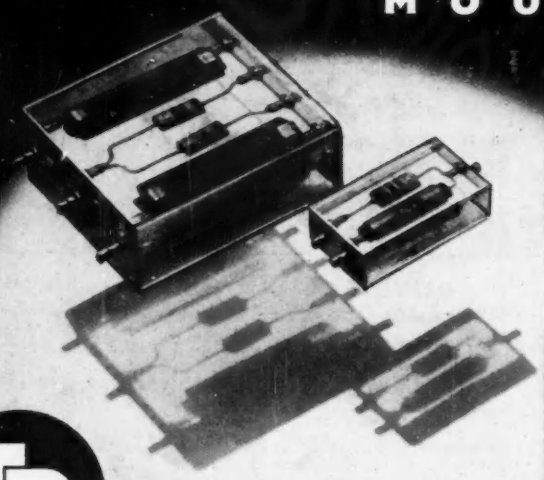

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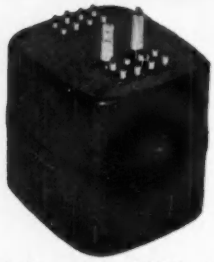

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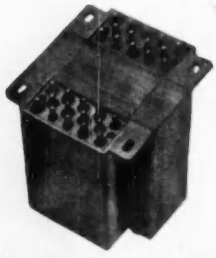

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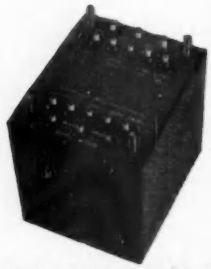

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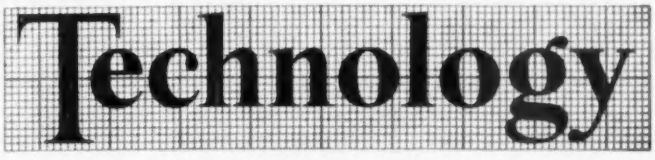


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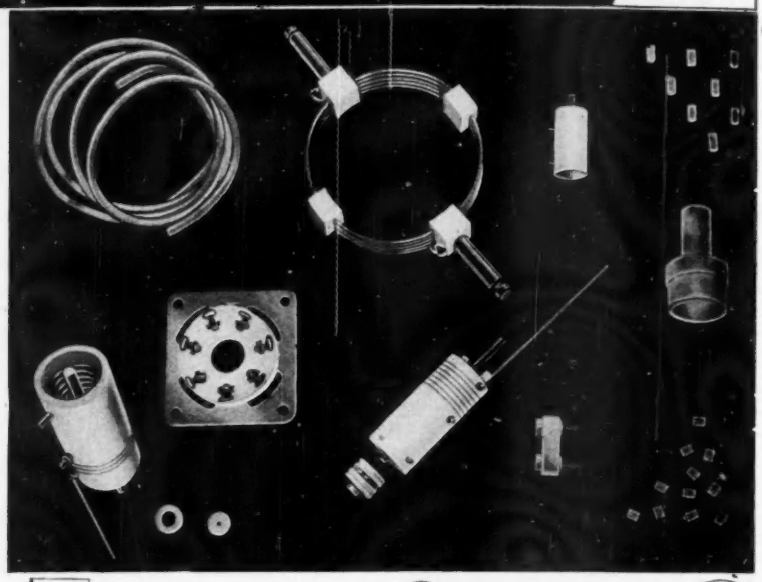

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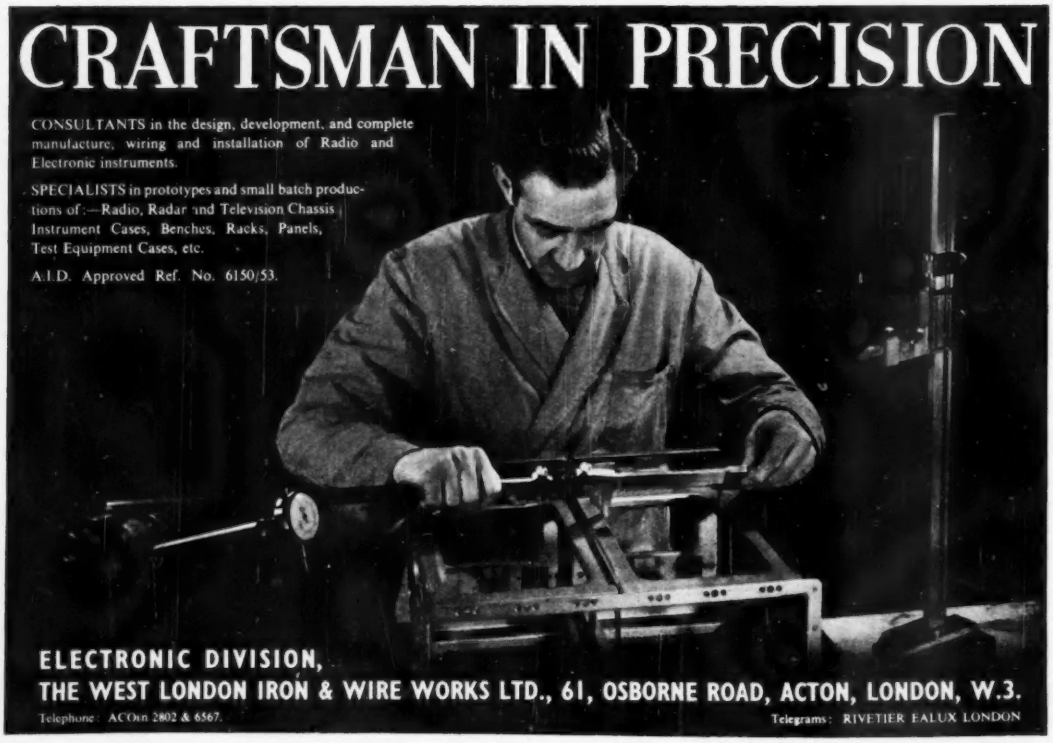

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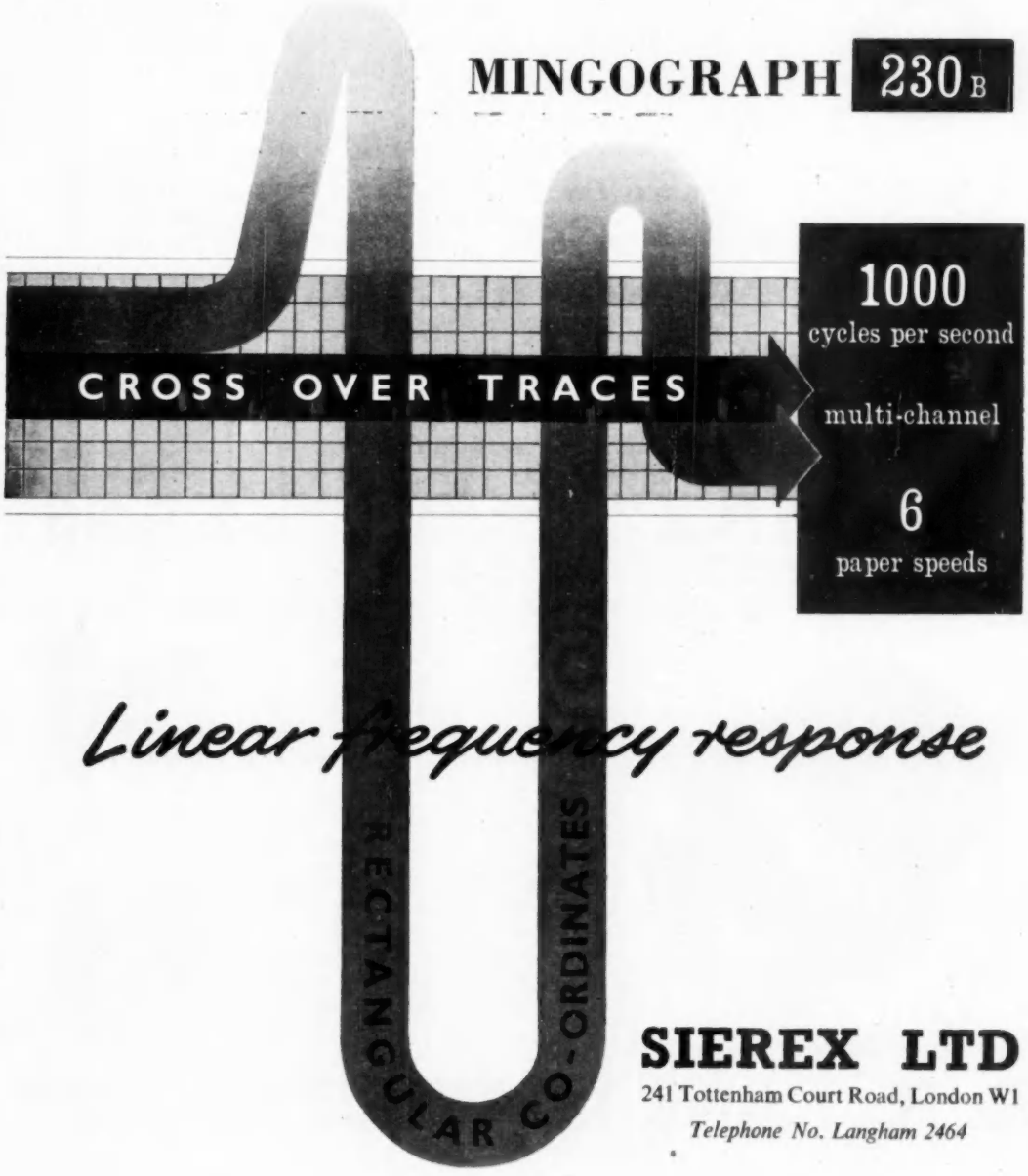


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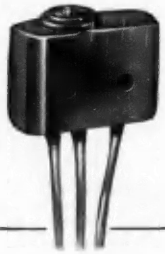

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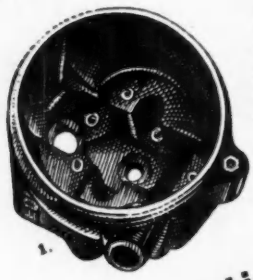

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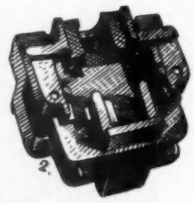

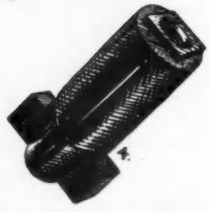

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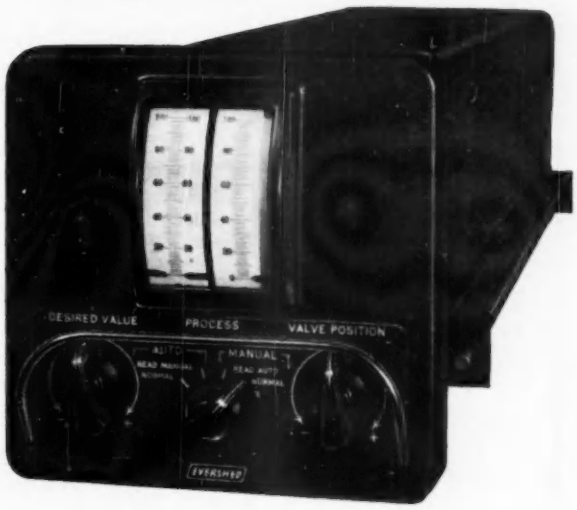


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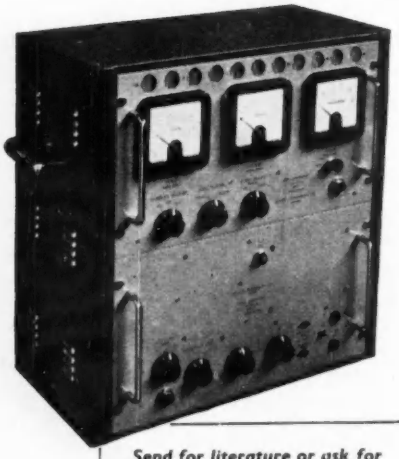

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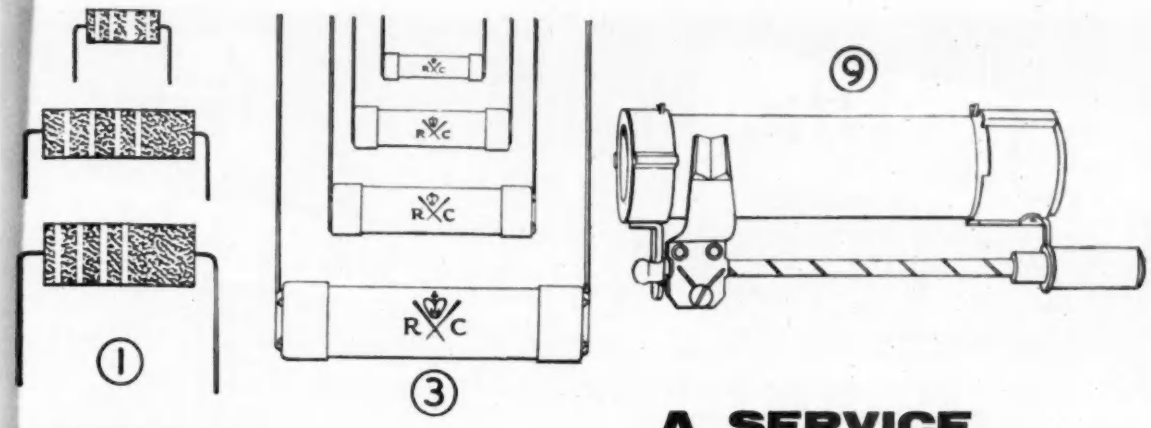


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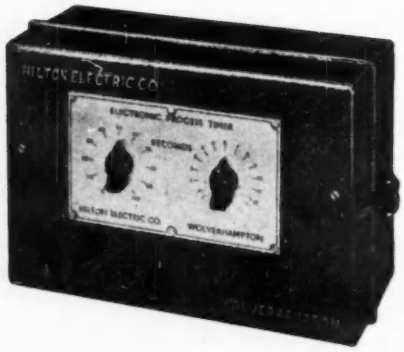


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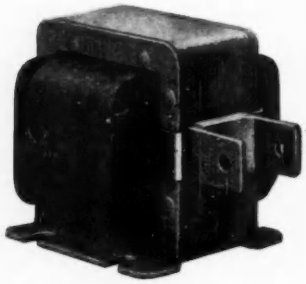

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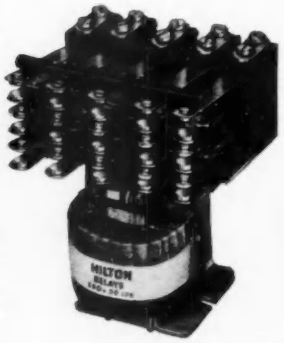


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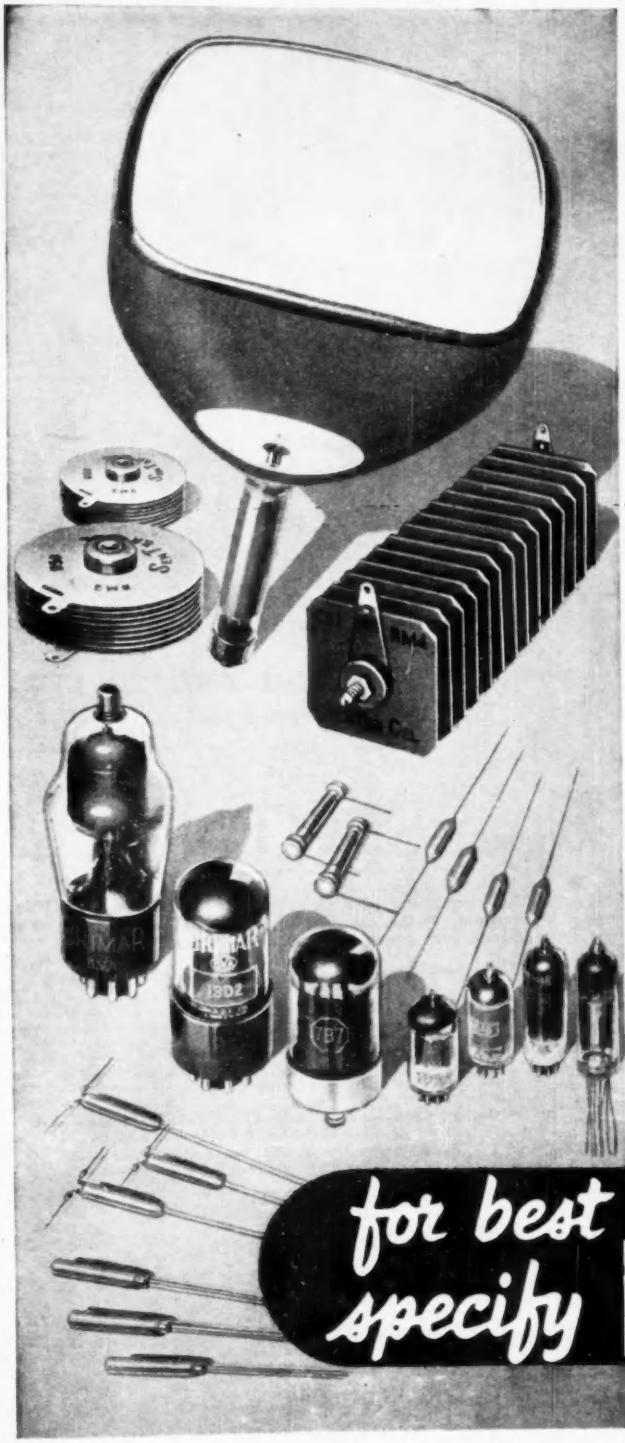

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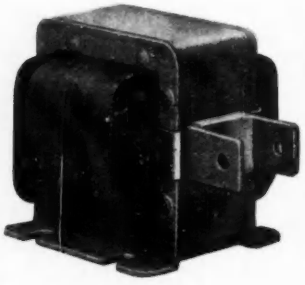

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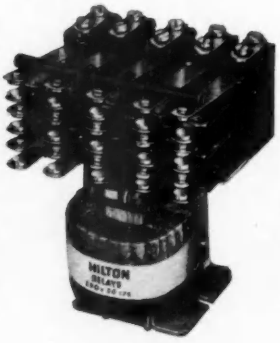


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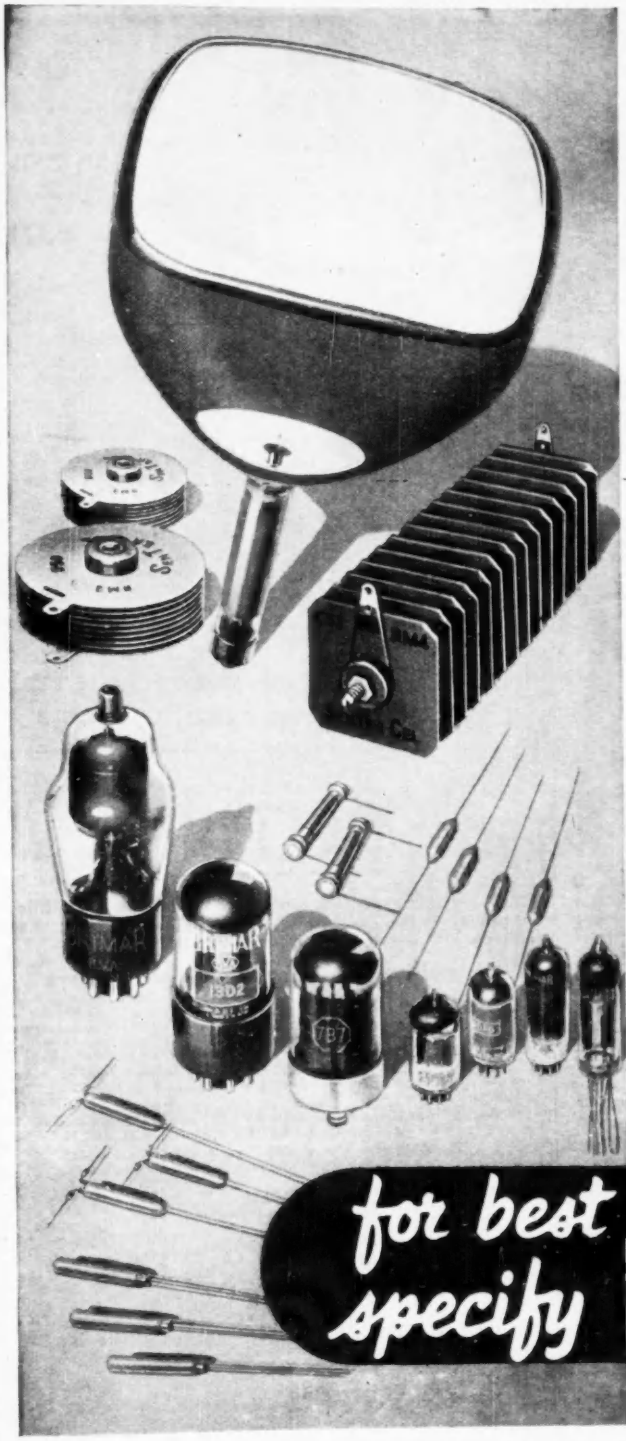

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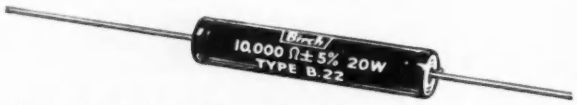
**9 SIZES — 10 to 250 WATT**

Fully vitrified porcelain former, winding 80/20 nickel chrome wire. High rating, liberal safety margin and tolerance.

**WIRE END TYPE**

**7 SIZES — 1½ to 30 WATT**




Axial or radial leads, tinned, securely fixed to the unit and capable of supporting the weight of the resistor, which can therefore be soldered in to equipment.

The specially developed enamel of these resistors, fuses to an intensely hard, high gloss surface giving complete protection to the winding under the most adverse conditions. The enamel is completely inert at all times and free from crazing, which allows wires of the finest procurable gauges to be safely employed. Hence a wide range of resistance values is available in each size

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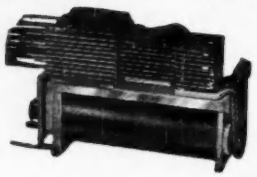

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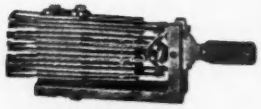

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Cylindrical bakelite screw on cover. 2 Contact. Ideal for amplifiers etc. 2/6 each, 24/- doz., £9 per 100.

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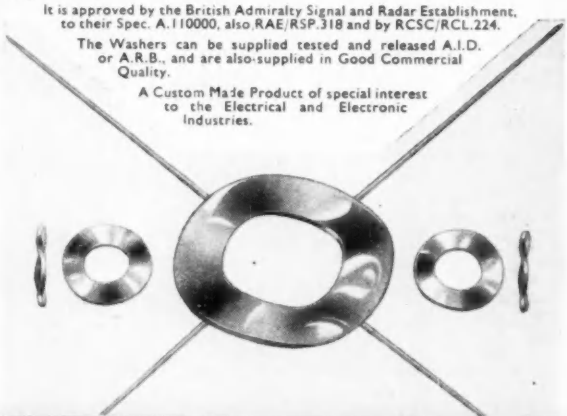
The Washers can be supplied tested and released A.I.D. or A.R.B., and are also supplied in Good Commercial Quality.

A Custom Made Product of special interest to the Electrical and Electronic Industries.



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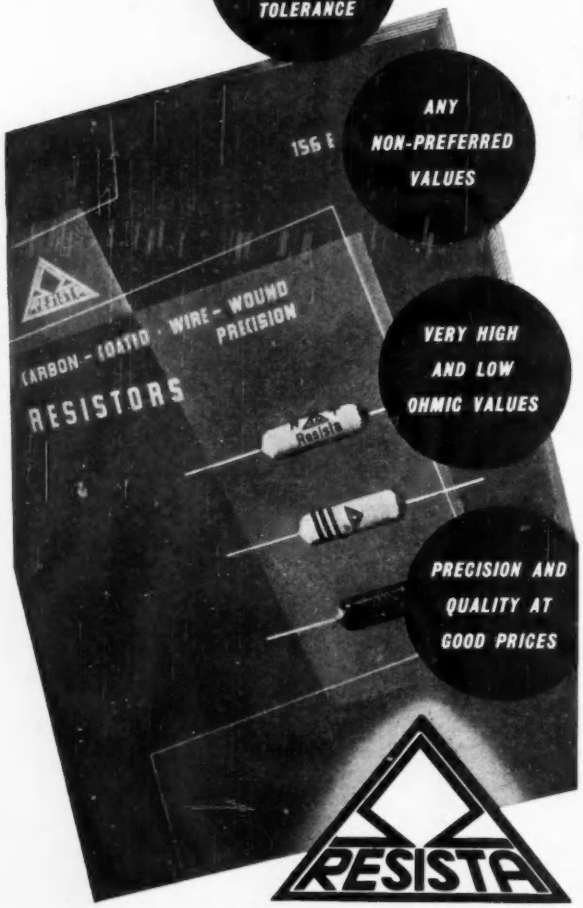
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# STANDARD-SIGNAL GENERATOR

*Type* **MS111**

**10 kc/s to 110 Mc/s ON FUNDAMENTALS**

**AM:** 0 to 90%

**ENVELOPE DISTORTION:**
0.5% at 30% AM
1.5% at 80% AM
below 5% at 90% AM

**OUTPUT:**
0.2 μV to 0.2 V emf in 2 dB steps from 10 or 75 Ω (10 and 50 Ω supplied on request)
0.2 to 2 V emf monitored from separate 200 Ω jack or up to 130 V across tuned load

**INTERNAL MODULATING OSCILLATOR:**
400 cps ± 3%
Distortion below 0.3%

Extremely wide frequency range and low-distortion AM make this instrument invaluable for lab. work. Output constant within ±1 dB on all ranges to 20 Mc/s. No side-band clipping. Incidental FM less than $3 \times 10^{-5}$ at 30% AM below 30 Mc/s.

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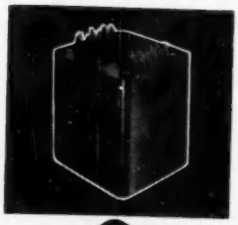
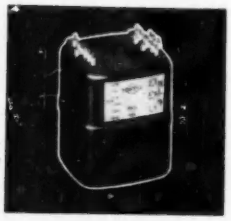
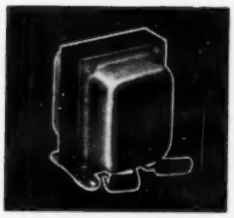
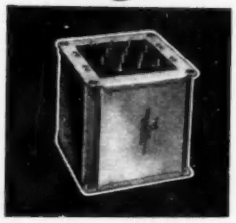


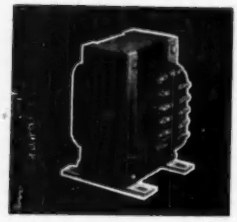
# TRANSFORMERS

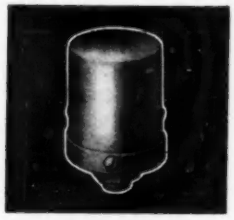
WODEN TRANSFORMER CO. LTD











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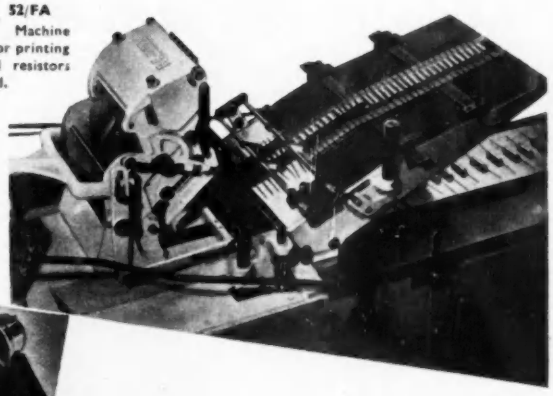
**MODEL ESSEX 52/FA**
Fully Automatic Machine specially designed for printing automatically small resistors with wires attached.



**The Rejafix Machine will print on any shape and on any material as well as paper, cardboard, fabrics, etc.**

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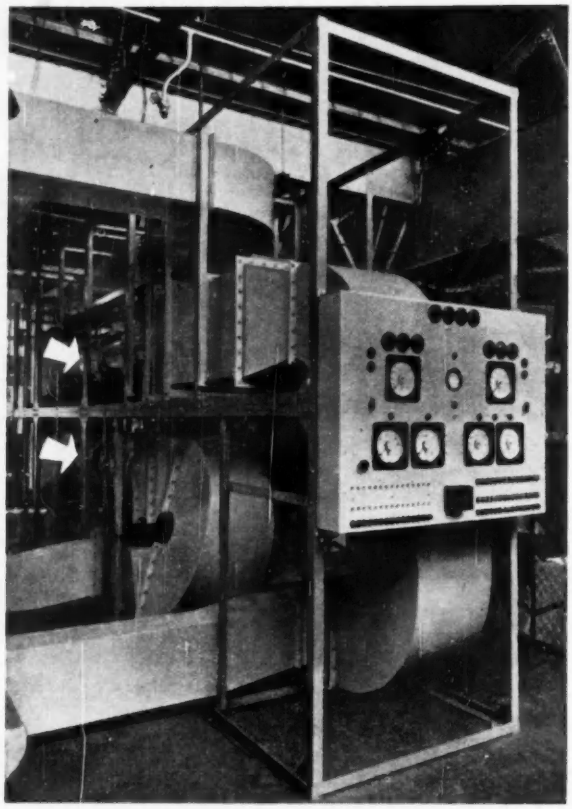

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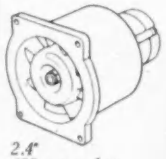
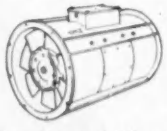
*May we send you Woods Small Fan Catalogue V3695?*

*Axial fans, 4½", 6", 7½", 8½" and larger.*



*2.4" 400 c.p.s. fan.*



*Two stage axial fans 7½" and larger.*

*Centrifugal fans, 3", 4½", 7".*

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AN ASSOCIATE COMPANY OF THE GENERAL ELECTRIC Co. Ltd., OF ENGLAND

# METEOR COIL WINDERS

(SWISS)

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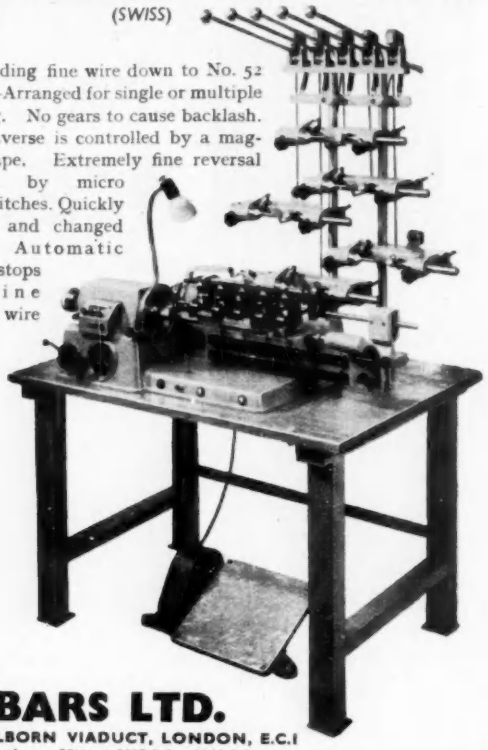

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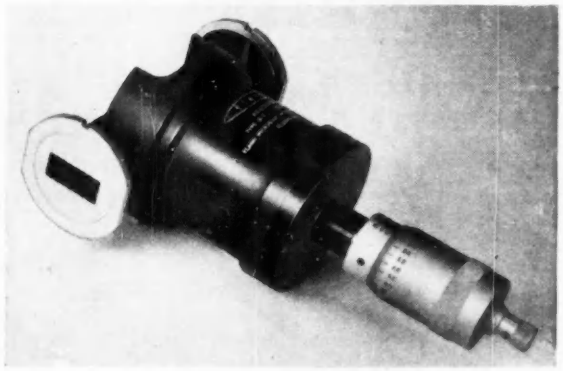
# WAVEMETER TYPE 16/7



## SPECIFICATION

| | | | |
|---|---|---|---|
| Mode of operation | TEoi | Calibration accuracy | 1 Mc/s |
| Waveguide | No. 16 | | 5 Mc/s |
| Q unloaded | 30,000 | Discrimination | 200 Kc/s |
| Q loaded | 10,000 | Micrometer Divisions | 0.0002" |
| Frequency range | 8.5 KMc/s to 12.5 KMc/s, 8.5–10 KMc/s, 10–12.5 KMc/s | | |

PRICE **£65** (in the U.K.)

*DELIVERY TWO MONTHS OR LESS*

**other details on request**

*Precision Instruments are made in all Waveguides from No. 10–12*

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*PROMPT DELIVERY*

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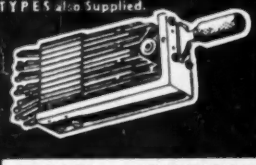
CONTACTS up to 8 c/o's Tropicalizing and impregnating to order.
600 and HIGH-SPEED TYPES also Supplied.



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**ALL POST OFFICE EQUIPMENT**

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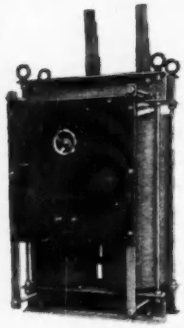
**TRANSFORMERS LARGE OR SMALL**



The illustration is of a 60 KVA Transformer with 5,000 amp. Secondary, with tapped Primary to give secondary voltage variation from 12 volts to 4 volts. Primary tap changes are made with a rotary switch as shown. These Units are designed and tested to BSS 171 where applicable, or appropriate B.S. Specification.

This is a typical example of our "C" Core range. We manufacture both open and hermatically sealed types, wound to customers specifications. This range extends from 10 VA to 1.6 KVA at frequencies up to 2,000 cps.

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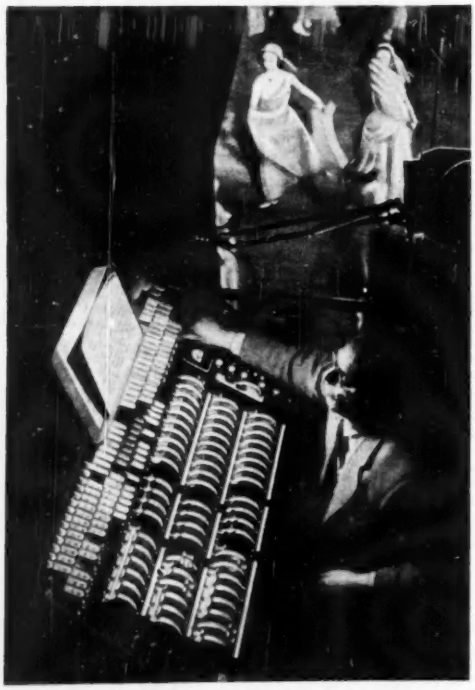

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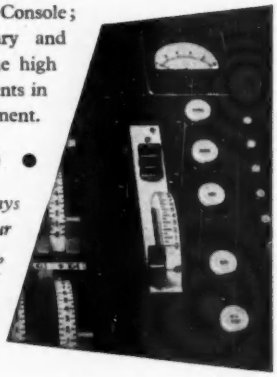

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Eliminate the need for solid brushings and tapping, use HELI-COIL PUSH-TYPE INSERT the ready-made screw thread for moulded and plastic parts, die cast alloys, powdered metals, all soft light materials and many hard metals. Pushed directly in drilled, cast, or moulded, blind or through holes, this is the ideal low-cost, volume production, fastening method. A few shillings in tooling is all you need for up to 1,200 holes and more per hour.

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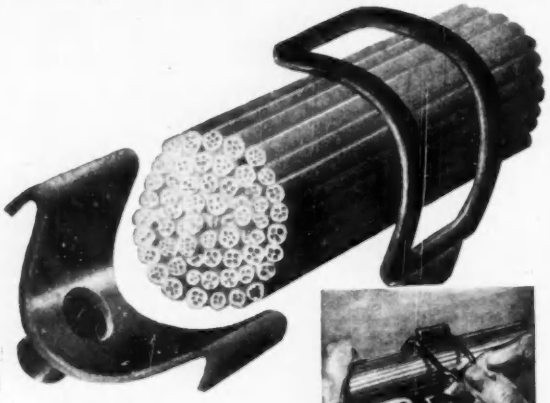

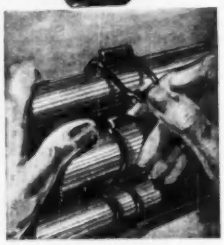

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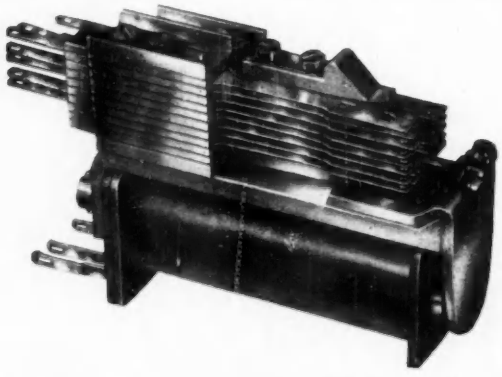

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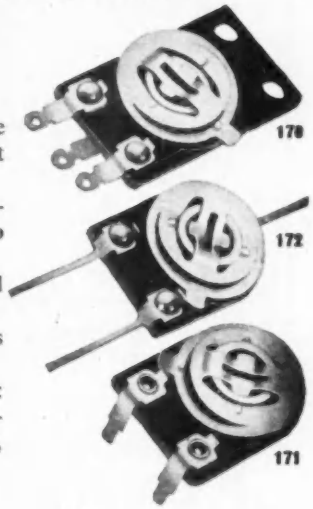
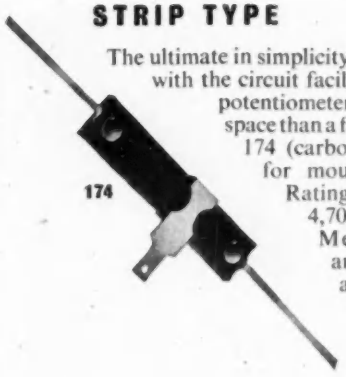



These pre-set variable potentiometers are robust and easy to adjust.
Type 170 is for independent mounting on two holes.
Type 171 is for printed circuits.
Type 172 has 1" leads for mounting in wiring.
Law: Linear. Values: 4,700 ohms to 2·2 Megohms. Tolerance ± 20% 1/10 Watt rating.

### STRIP TYPE

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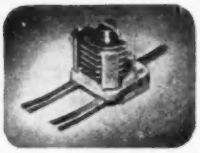

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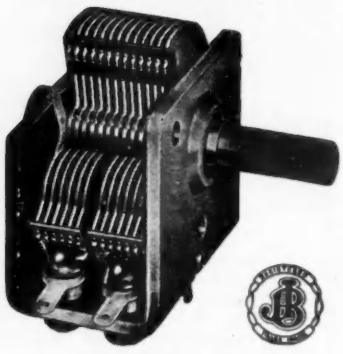

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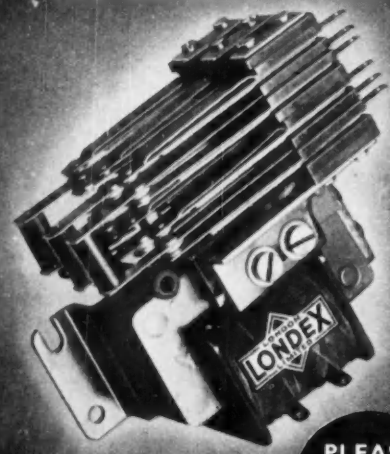


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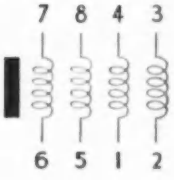


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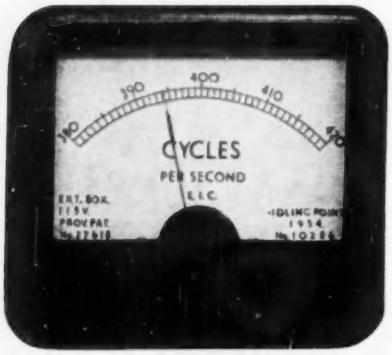


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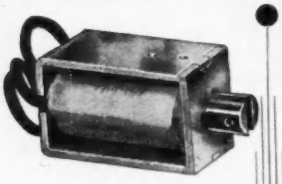

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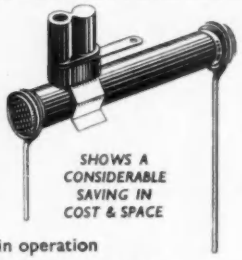

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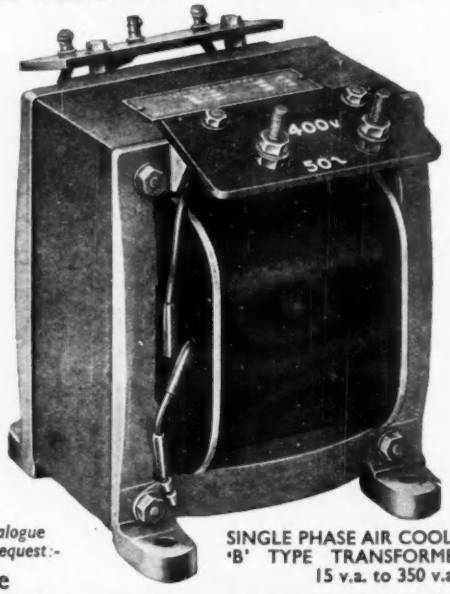


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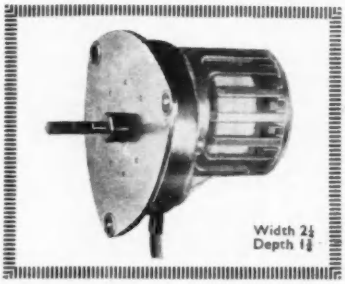


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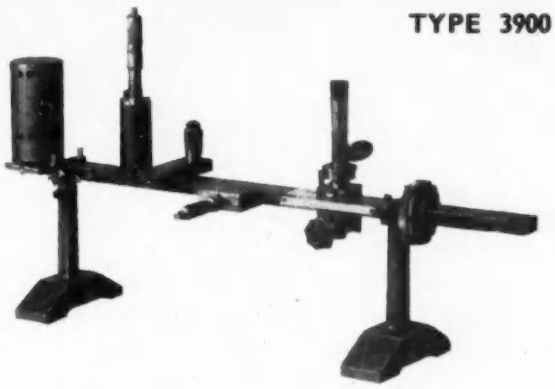

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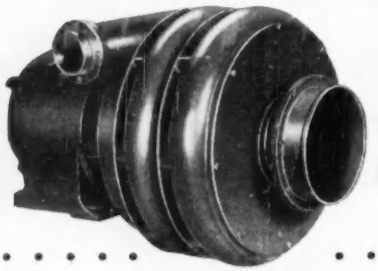

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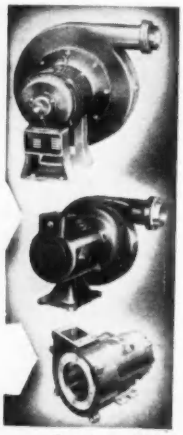

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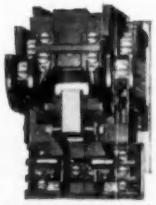

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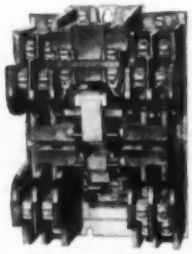

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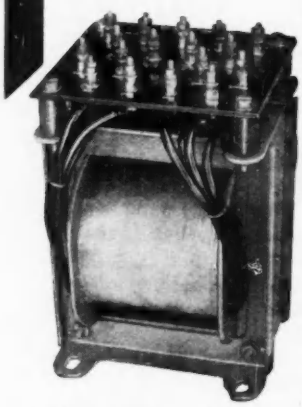

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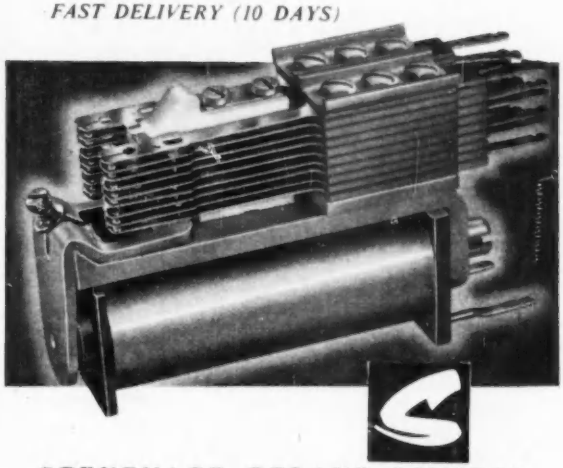

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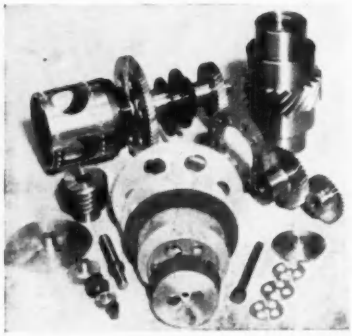

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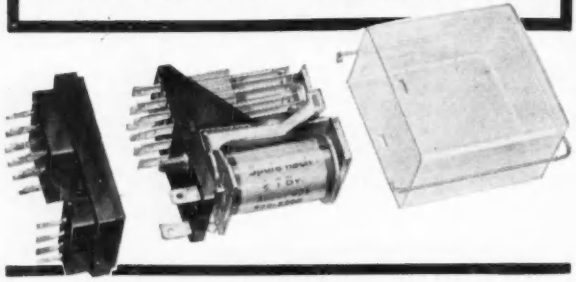

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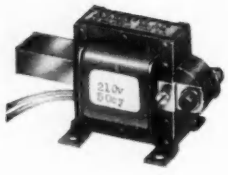

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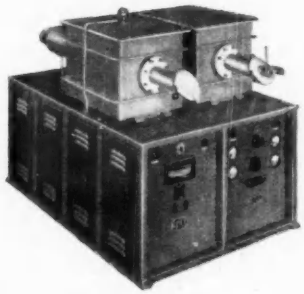

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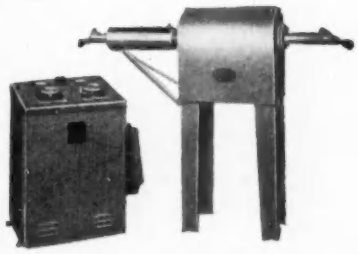

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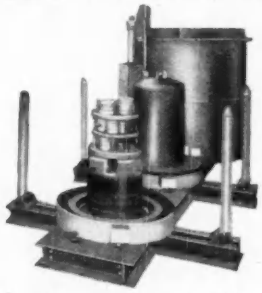

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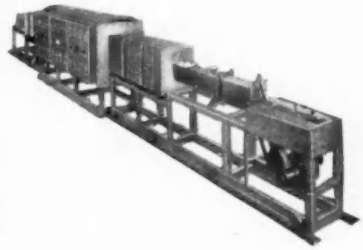

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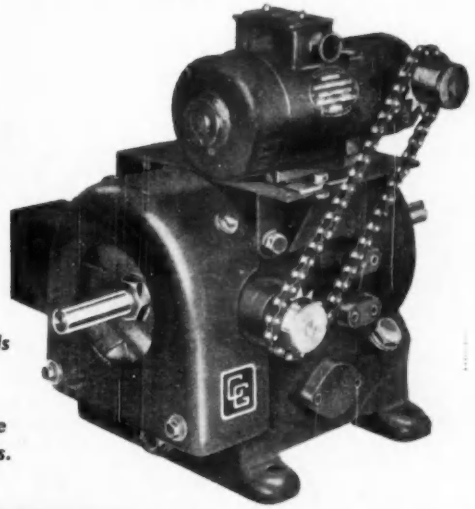

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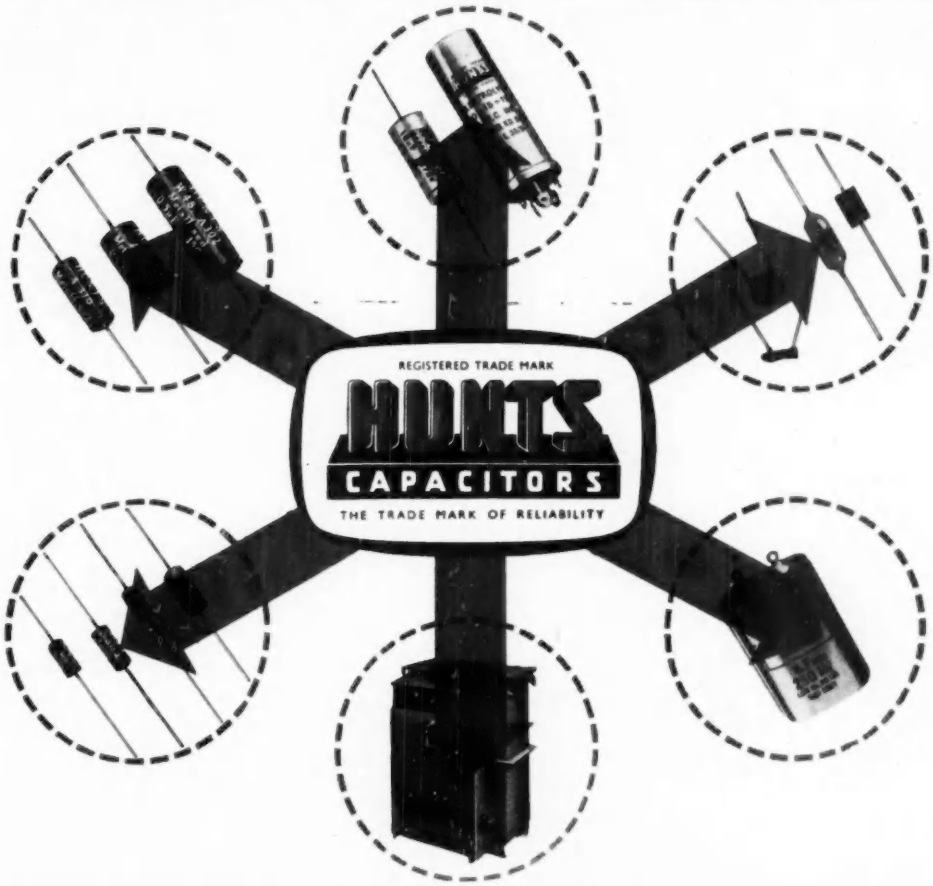


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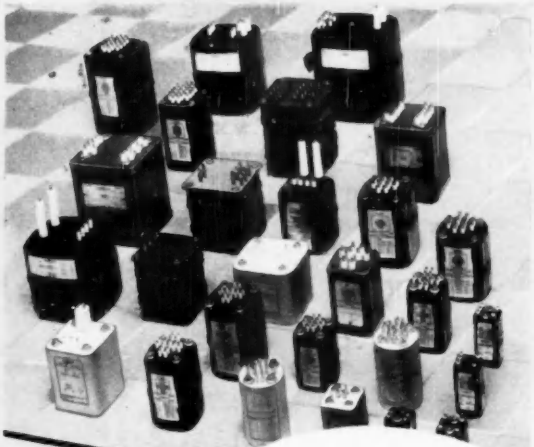

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